UCRL-13591

Final Report

PRESENT AND FUTURE CAPABILITIES FOR BATTLEFIELD RADIATION HAZARD ASSESSMENT

PO 1425605

By: H. LEE R. W. MILLICAN W. F. HARDMAN

STANFORD RESEARCH INSTITUTE
Menlo Park, California 94025 · U.S.A.

Final Report *November 1973*

PRESENT AND FUTURE CAPABILITIES FOR BATTLEFIELD RADIATION HAZARD ASSESSMENT

By: H. LEE R. W. MILLICAN W. F. HARDMAN

Prepared for:

UNIVERSITY OF CALIFORNIA
LAWRENCE LIVERMORE LABORATORY
LIVERMORE, CALIFORNIA

CONTRACT AT(04-3)-115
P/A No. 95

SRI Project 2605

Approved by:

GEORGE HOPKINS, *Director*
Operations Evaluation Department

ERNEST J. MOORE, *Executive Director*
Engineering Systems Division

ACKNOWLEDGMENTS

The authors acknowledge with gratitude the advice and direction of Mr. Albert Schiff, the Lawrence Livermore Laboratory Technical Coordinator of the research herein reported.

CONTENTS

V CURRENT CAPABILITIES (Continued)

ILLUSTRATIONS

TABLES

GLOSSARY

AACOMS	Army area communications system
AARS	advanced aerial radiac system
ABN	airborne
AC	analysis console
ADP	automatic data processing
ALT	alternate
AM	amplitude modulation
APC	armored personnel carrier
ARMD CAV	armored cavalry
ARTY	artillery
ASCII	American standard code for information interchange
AVN	aviation
BASS	battle area surveillance system
BDE	brigade
BDU	battery display unit
BIC	battlefield information center
BICC	battlefield information control center
BN	battalion
bps	bits per second
BTRY	battery
C_4	computer center control console
CAV	cavalry
CBRC	chemical-biological-radiological center
CBRE	chemical-biological-radiological element
CBTI	combat intelligence

CCC	central computer center
CF	command and fire direction
CNCS	communications network control station
CO	company
COMD	command
COMSEC	communications security
CP	command post
CPU	central processing unit
DIV	division
DIV ARTY	division artillery
DIV TOC	division tactical operations center
DS	direct support
DTA	data terminal assembly
DTU	data transmission unit
ENGR	engineer unit
F	fire direction
FATA	field artillery target acquisition (battery)
FDC	fire direction center
FEBA	forward edge of the battle area
FFMED	fixed format message entry device
FM	frequency modulation
FO	forward observer
FSE	fire support element
FSK	frequency shift keying
FY/TY	fission yield/total yield ratio
GDD	group display device
GS	general support
GZ	ground zero
HOB	height of burst
IBCS	integrated battlefield control system

INF	infantry
I/O	input-output
KG	key generator
LED	light emitting diode
LO	liaison officer
LOS	line of sight
MECH DIV	mechanized division
MID	message input device
MIOD	message input/output device
MMRD	miniature multipurpose radiac device
MNVR	maneuver
MODS	mortar delivered sensor
MPCU	monitor patching and control unit
MSL BN	missile battalion
MURP	multichannel universal relay package
NBC	nuclear-biological-chemical
OP/INTEL	operation/intelligence
PLAT	platoon
RAOC	rear area operations center
RATT	radio teletype
RCC	remote computer center
RECON	reconnaissance
REG	regiment
REMBASS	remotely monitored battlefield sensor system
RR	radio relay
SCM	sensor control module
SEC	section
SIG	signal corps
SP	self propelled
SQDN	squadron

SRI	Stanford Research Institute
SRU	sensor reporting unit
SSB	single side band
STANO	surveillance, target acquisition, and night observation
SUP	small unit package
SVC	service unit
TACFIRE	tactical fire direction system
TCC	tactical control console
TOC	tactical operations center
TOS	tactical operations system
TRP	troop
UCR/T	universal control receiver/transmitter
UGS	unattended ground sensor
USAC&GSC	U.S. Army Command and General Staff College
VFMED	variable format message entry device

I INTRODUCTION

A. Background

Tactical nuclear warfare may be defined as a conflict where the application of nuclear weapons is limited to the defeat of opposing military forces in a military theater of operations. The primary advantage of using nuclear weapons is the rather large increase in fire power (measured by the capabilities of its blast, thermal, and initial nuclear radiation energy releases for destroying enemy military resources including troops in the theater) that can be gained with relatively low personnel employment and logistics support. The detonation of nuclear weapons, however, also releases radioactive fission products to the atmosphere. The return of these fission products to the earth's surface after being buoyed aloft and translated by the prevailing winds is known as radioactive fallout.

In a military theater of operations where tactical nuclear weapons are used by either opposing forces or by both forces, it can be expected that hazardous concentrations of fallout will be deposited on various battlefields and other areas. Also, during the early stages when the fission products are still airborne, the fallout-contaminated air volume can also be hazardous to pilots of penetrating aircraft. Since the overexposure of troops to fallout radiation could result in their debilitation or death, the awareness of the actual or predicted fallout locations and their intensity geometries at any time is essential for selecting appropriate tactical maneuvers.

B. Objectives

The objectives of the work reported herein are to gather, organize, and interpret information regarding the following aspects of fallout radiation in battlefield situations:

- How the operational capabilities of U.S. combat forces can be affected.
- The fallout assessment equipment and information required to return U.S. combat forces' capability to acceptable levels.
- Current U.S. combat forces' capability to respond to battlefield fallout situations, including areas of potential improvement.
- The utility of a system having fallout sensing, communication, processing, and display elements.
- The desirable characteristics of deployment, sensors, communications, data reduction, and displays for a system for radiation hazard assessment.

II DOCTRINE

A. Tactical Nuclear War Concepts

Although it seems to be generally agreed that a tactical nuclear war may develop, opinion is divided on its course once it starts. Current planning of tactical nuclear engagements includes the use of restraints to avoid escalation; the employment of weapons to minimize civilian casualties; and restrictions on the yields, the number of weapons, and the types of burst that can be employed. However, doctrine warns that preconflict attempts to predict the ultimate level of nuclear use could be misleading and disastrous.[1*] Whereas, on the one hand, there are those who believe that should tactical nuclear weapons be employed, they would be employed one at a time (where each employment would be predicated on the enemy's response to a previous employment), on the other hand there are those who believe that once the employment of nuclear weapons is initiated, every effort will be made to maximize nuclear employment in order to destroy the opponent's military capabilities. In the first case the battle would be highly structured; in the second case it would be highly unstructured. In both areas it is anticipated that the tactical nuclear battle will be short-lived. In the first case a negotiated termination is anticipated; in the second case an opponent's capabilities to continue will be destroyed.

There also exists the rationale that the employment of airbursts by both opponents will predominate, and for this reason fallout on the battlefield will be minimized and therefore will not be a significant

*References are listed at the end of this report.

battlefield operational factor. There is also reason to believe, however, that possible opponents are not currently restricted to this concept of tactical nuclear weapon employment. Also, the radioactive nuclear debris, even from tactical air bursts, can be subjected to rainout or washout and might be deposited on the battlefield. In summary, the fallout events and the battlefield radiological environment can vary over a wide range, as can the nuclear battle itself.

B. Tactical Nuclear Capabilities

The weapon yields generally applicable for tactical nuclear warfare are from the subkiloton range to the hundred-kiloton range. This does not, however, preclude the possibility that weapons in the megaton range will be detonated on a tactical nuclear battlefield.[2] The weapon delivery capabilities within a division are perhaps several score per day of assorted yields, which might approach a megaton of total yield.

C. Fallout

Shallow subsurface, surface, and low air bursts will all produce local fallout. In addition, under certain meteorological conditions, tactical yield air bursts will also produce local nuclear contamination. This phenomenon is called "rainout" or "washout." The size of the iso-intensity fallout ground patterns is primarily a function of weapon yield, as are the fallout arrival and fallout cessation times. The shapes of the patterns are dependent on the winds aloft acting on the fallout particles as they descend. Current knowledge on rainout and washout is relatively limited, but it is acknowledged that the locally deposited radioactivity from these phenomena could exceed those from fallout.[3]

The area covered within various iso-intensity ranges (referenced to one hour after burst) by fallout per kiloton of weapon yield will vary considerably. In general, however, the area increases with decreasing intensity and can be approximated as follows for a one-kiloton burst:[4]

Iso-intensity Range (rad/hr at 1 hr)	Area (sq miles)
>1000	0.05
500-1000	0.3
100-500	2
10-100	30
1-10	100

If it is assumed that a division's area of responsibility, in a nuclear combat deployment, is in the neighborhood of about 1000 square miles, then a single 1-kT surface burst would only contaminate a few percent of this area in excess of 10 rad/hr, and only a fraction of one percent in excess of 100 rad/hr. The fallout from the surface detonation of the higher yield tactical weapons can generally be expected to extend beyond a division's area of responsibility. Nevertheless, a few 100-kT surface bursts under relatively light variable winds could conceivably contaminate virtually the entire division's area of responsibility in excess of 100 rad/hr.

The arrival time of fallout after a surface burst depends on one's location with respect to the burst location, the weapon yield, and the effective velocity of the winds carrying the fallout. In general, the fallout arrival times for a tactical nuclear weapon detonated within a division's area of interest will be in the range from a fraction of one hour to perhaps a maximum of two hours. The duration of fallout at any single location from a single surface burst can also be expected to span a fraction of one hour to about two hours. Fallout from detonations outside of the division's area of interest may have arrival times and duration times of a few hours. However, in the case of multiple surface bursts, either detonated at the same time or at different times, the fall-out duration time at any location could be extended considerably.

Within the first few hours of a nuclear burst the radioactive decay of fallout is relatively rapid and the exposure rate will decrease by a factor of ten from one hour after burst to about six or seven hours after burst. On the other hand, the exposure rate at half an hour after burst will be more than double the H + 1 hour exposure rate. Since a location may receive fallout from several surface bursts, however, its radiation exposure rate history will depend on the various arrival times and decay rates.

The exposure dose received by troops in the field depends on the exposure rate, exposure time, and the protective shielding taken. Examples of the protection afforded by various vehicles and other geometries are as indicated in Table 1.

D. Operations

A primary military mission of both opposing forces is to destroy the enemy's capability to wage war. A significant part of this capability is vested in nuclear delivery capabilities and consequently "destruction of the enemy nuclear delivery means will become a principal objective" and "the maneuver of nuclear fires rather than troops will become a dominant feature of the nuclear battlefield."[1]

There are two major decision criteria in fallout areas:[6] (1) tactical demand dominant and (2) radiation hazard dominant. Tactical demand is dominant when (1) it is clearly perceived that an important mission can still be fulfilled and (2) mission fulfillment is perceived to be more important than the anticipated radiation casualties. Otherwise, the situation is considered to be radiation hazard dominant and the major concern is exposure dose minimization. In any situation, however, the

Table 1

TRANSMISSION FACTORS FOR RESIDUAL RADIATION

Environmental Shielding	Transmission Factor
Vehicles	
M60 tank	0.04
M48A2 tank	.02
M41 tank	.1
M113 APC	.3
XM 104 SP howitzer	.5
M107 SP gun	.4
M108 SP howitzer	.3
M109 SP howitzer	.2
M110 SP howitzer	.4
XM106 SP mortar	.3
M125A SP mortar	.3
M114 reconnaissance vehicle	.3
M116 cargo vehicle	.6
M548 cargo vehicle	.7
M88 recovery vehicle	.09
M578 recovery vehicle	.3
M577 command post carrier	.3
M551 armored reconnaissance/ABN assault vehicle	.2
M728 combat engineer vehicle	.04
Trucks	
1/4-ton	.8
3/4-ton	.6
2-1/2-ton	.6
4-ton to 7-ton	.5
Structures	
Multistory building	
Upper floor	.01
Lower floor	.1
Frame house	
First floor	.6
Basement	.1
Shelter, underground (3-foot earth cover)	.0002
Foxholes	.1

Source: Ref. 5.

number of alternative actions is very limited. The options are to move to another location or to stay at the position. The reasons for moving are (1) to gain a tactical advantage and (2) to seek a safer location. The election of the best action to reduce radiation exposure, regardless of the decision criteria, requires knowledge of the radiological hazards within the areal extent of a unit's ability to move.

A primary distinction between nuclear and nonnuclear operations is the wide dispersion of forces and the great depth of the zone of combat.[1] Dispersion of units reduces vulnerability to enemy nuclear weapons and permits the use of friendly nuclear weapons within the battle area. A combined arms team is the organization most suited for operations in a tactical nuclear environment; e.g., a maneuver battalion containing tank and infantry companies, engineer units, air defense elements, and field artillery. To operate effectively over the increased separation distances between units, control will be decentralized and small-unit (battalion or smaller) leaders will operate on their own initiative for a long time. Although division control of operations will be decentralized, and subordinate commanders will operate on their own initiative, they will be in conformance with the division overall plan.

Offensive operations in a nuclear environment require detailed early planning.[1] Intensive nuclear fire preparation followed by the rapid advance of widely dispersed maneuver units characterize the attack. The concept of defensive operations in a nuclear environment is based on the employment of small mobile units, well supported by nuclear weapons. The depth of the defensive area is increased and the attacking enemy forces are subjected to extensive nuclear fires as they attempt to penetrate the battle area.

E. Current Procedures

As currently constituted, radiological assessment consists of two systems: a prediction system and a measurement system, where the information provided by one can be used to augment the other.[6] Once nuclear employment has occurred, the fallout prediction procedures go into effect.[5,7] Nuclear burst data are promptly reported to the division nuclear-biological-chemical (NBC) center. Headquarters units of field artillery and air defense artillery battalions and air defense artillery batteries are normally the units reporting nuclear burst data. The essential nuclear burst information required for the preparation of a fallout prediction are: (1) location of ground zero (GZ), (2) yield, (3) time of burst, (4) height of burst (HOB), (5) fission yield-total yield ratio (FY/TY), and (6) meteorological data. The meteorological data are provided by the weather detachment of the division staff. For friendly bursts, height of burst and FY/TY ratios are provided by the firing units, but for enemy bursts there are no accurate means for estimating HOB and FY/TY, and the types of bursts are only reported as surface, air, or unknown. The FY/TY ratio is assumed to be unity. The NBC center in turn disseminates fallout predictions to subordinate echelons. Periodic radiological monitoring is also initiated immediately on the initiation of nuclear employment. Continuous monitoring is initiated when a periodic check reveals radiation, on receipt of a fallout warning, on seeing a nuclear burst, or on order. Reports are rendered as prescribed changes in radiation levels are reached. Since fallout will not occur immediately, except in the vicinity of the burst point, the reporting of monitoring data will follow the reporting of nuclear burst data. As more nuclear bursts occur, however, it can be anticipated the NBC center will be receiving a mix of both types of reports.

Radiological surveys are conducted only when essential radiological contamination data cannot be obtained from monitoring reports by units within the contaminated area. This implies that radiological surveys are not conducted concurrently with monitoring activities but afterwards, presumably if the monitoring data are found to be inadequate, if a unit is required to move through an area where the radiological situation is unknown, or perhaps when it is deemed safe to move through such an area after some fallout has occurred. Since the nuclear debris from a surface burst descends over a period of hours, since a number of surface bursts can be expected to be detonated over a considerable period of time at various locations, and since monitoring will be continuous under these conditions where applicable, it is speculated that radiological surveys, particularly ground based surveys, will be delayed until conditions become more stable. An exception would be a case wherein a unit was in a high dose rate area, had to move, and had to determine the exit route with the least risk. The speed with which aerial radiological surveys can be accomplished would tend to make them more suited to immediate operational needs than ground surveys.

The NBC center at division headquarters receives radiological data from subordinate and attached units to the division, charts the data, and disseminates the charted information to interested staff officers and to all units located in the division area. The radiological prediction data are reported at once. These are then followed by radiological monitoring data and radiological survey data as they become available. The NBC center also plans, directs, and coordinates radiological surveys. The data obtained from NBC center directed surveys are forwarded directly to the NBC center. Monitoring data and data from surveys directed by subordinate units are screened and consolidated by intermediate headquarters and forwarded through channels to the NBC center.

III SYSTEM COMPARISONS

A. System Utility

The utility of any system depends on the conditions of its application; that is, a system may be adequate for one set of conditions and inadequate for another. Where the utility of one system is to be evaluated, it can be tested for several sets of conditions, each requiring a different level of performance demand. The system's utility can then be rated for each set of conditions. It is essential, however, that the test conditions be representative of conditions that are likely to occur; that is, a system that is highly effective in a condition that seldom occurs has little utility.

A battlefield radiological assessment system has utility only if it can supply the required intelligence when it is needed. The required intelligence is that type of intelligence about fallout radiation that is applicable to battlefield operations planning. Ideally, the battlefield operations planner would like to know what the radiological conditions will be or are likely to be at the time of the planned operations. A measurement system is not a predictive system, however, and it can only supply data based on what the radiological conditions were at the time of measurement; i.e., any subsequent change other than radioactive decay cannot be predetermined.

Within a battle zone, the radiological conditions will change as more weapons are detonated and more fallout from past and future weapons is deposited. It can therefore be expected that, besides radioactive decay, the radiological conditions at the time of monitoring will be different than they are when an operation (that was planned with the monitoring data) is executed. The amount of change over this period of time will depend on the length of the period and the rate of radiological change. Thus, for radiological assessments based on prediction, if there are no detonations between the time of the prediction and operation execution, the prediction remains valid. For radiological assessments based on measurements, if there were no fallout between the time of measurement and the time of operational execution the battlefield radiological environment would be known (since the radioactive decay rate can be estimated). It follows that, as the number of detonations increases between those two times the prediction becomes more invalid, and as the amount of fallout increases between the two times the battlefield radiological environment will become increasingly different from the measured environment. Therefore, for the case where the battle is being fought, the shorter the time lag between radiological assessment and operational maneuvers, the greater will be the assessment's potential value.

There will always be a time lag, no matter how short, associated with radiological assessments based on measurements. A radiological assessment based on prediction, on the other hand, could in some cases eliminate the time lag because it would predict the radiological environment for a future time.

B. Measurement Systems

Where the radiological assessments are based on measurements--i.e., monitoring or survey data--the error, E_{ms}, of the measured value at t_1 with respect to the radiological environment at the operation execution time, t_3, at a single location is, in percent:

$$E_{ms} = \left[\frac{M + \int_{t_1}^{t_3} at^b \, dt}{M - E_m} - 1 \right] 100 \qquad (1)$$

where

E_m = the error in the measurements

M = the assessed value of the radiation at t_1 decayed to t_3

at^b = the rate of change in the radiation exposure rate due to additional fallout between t_1 and t_3.

The rate of change--i.e., the values of a and b--in an actual nuclear battle cannot be estimated, however, nor is it likely to be a continuous function over the period t_1 to t_3. For comparative purposes, it can be assumed to be constant; i.e., $b = 0$. If $b = 0$ then

$$E_{ms} = 100\left[\frac{M + a(t_3 - t_1)}{M - E_m} - 1\right] \qquad (2)$$

C. Semipredictive Systems

The semipredictive system is defined as one where fallout prediction methods and procedures are used in conjunction with early fallout measurements to project the measured data to later fallout depositions (usually at locations more distant from the detonation points). In this system the measured arrival times and the deposition rates are data that provide estimates of HOB and FY/TY that are not available in the prediction system. For this reason it can be assumed that, with adequate input data and an adequate fallout model, the fallout deposition at later times (at more distant locations) can be estimated from data obtained on the earlier fallout at closer locations.

There are problems associated with the semipredictive system, however. An obvious problem is the commingling of the fallout particles from more than one weapon as they descend, which obscures the resolution of the data.

In the semipredictive system, the error, E_{ss}, of the projected fallout at t_2 based on measurements at t_1 with respect to the radiological environment at the operation execution time, t_3, at a single location is, in percent:

$$E_{ss} = \left[\frac{M + \int_{t_2}^{t_3} at^b dt}{M - E_s} - 1 \right] 100 \qquad (3)$$

where

E_s = the error in the semipredictive assessment method

M = the assessed value of the radiation at t_2 decayed to t_3.

It can be anticipated that E_s will be larger than E_m; but, on the other hand, since the system time lag between t_1 and t_3 is similar for the measurement system and the semipredictive system, and t_2 is an intermediate time between t_1 and t_3, the time between t_2 and t_3 is shorter than it is between t_1 and t_3. For a constant rate of radiological change

$$E_{ss} = 100 \left[\frac{M + a(t_3 - t_2)}{M - E_s} - 1 \right] \qquad (4)$$

D. Predictive Systems

The prediction systems based on nuclear burst data predict the radiological environment further into the future than do the semipredictive systems, because time is not lost awaiting the arrival of early fallout. Consequently the time between t_2 and t_3 is shorter for a prediction system than for a semipredictive system for similar system lag times, except when $t_3 - t_2 = 0$ for both systems. For a constant rate of radiological change, the error, E_{ps} of the predicted value for

t_2 with respect to the radiological environment at the operation execution time, t_3, at a single location is, in percent:

$$E_{ps} = 100\left[\frac{M + a(t_3 - t_2)}{M - E_p} - 1\right] \qquad (5)$$

where E_p, the error in the current prediction procedure, could be very large. For example, if the type of burst is unknown and it is assumed to be a surface burst, when in reality it is an air burst, then $E_p = M$.

E. Discussion

A single surface burst of a weapon with a yield of about 20 or 30 kT could significantly change the radiological conditions over a large part of a division's area of interest. Because of this, and because of the nuclear capabilities of a division, one can expect that, should a nuclear battle occur, the radiological conditions on the battlefield could change rapidly from hour to hour over a considerable period of time--if a significant part of the detonations are surface bursts. Thus, unless the surface burst locations can be anticipated, there is no way of predetermining the radiologically safe areas with respect to some future time. Existing methods, however, are capable of delineating those radiologically hazardous areas that are or will probably be created by weapons that have already been detonated. It is with this type of radiological information that operational decisions must be made.

It was previously shown that a radiological assessment system based entirely on radiation measurements will give the most accurate information with respect to the time of the measurements. However, the effective time lag associated with that system permits a big change to occur in the radiological environment before an operation, based on the assessment, can be planned and executed. The overall accuracies of the three systems in forecasting the radiological environment for a planned operation depend on the accuracy of the assessment method, the assessed radiological status, the rate of change in the radiological conditions, and the time lag associated with each system. It should be noted that the locations with the least measured or predicted fallout will produce the greatest overall system errors with any additional fallout. Thus, in the no-fallout or low-fallout areas, the prediction system could be very useful in augmenting the measurement system. The measurement system determines the current status of these areas and the prediction system estimates the likelihood of near future changes.

IV OPERATIONS

A. Emergency Maneuvers

The basic maneuver options available to field units threatened by fallout are to remain in place or to move to another location. If a move to another location is desired, then there is an additional option on the selection of routes. In the event of nuclear fallout, some battlefield areas could be contaminated to hazardous levels. The situation permitting, troops deployed in those areas must move to a safer location; therefore, it is necessary that another location and a route to that location be selected.

In general, where the fallout producing bursts are far enough apart so that their patterns do not merge with one another in their high radiation rate zones, those units that find themselves in a hazardous fallout area are close enough to the contaminating burst to have perceived the direction and the approximate distance to ground zero. In the daylight hours on a fairly clear day, they would also be able to discern whether the major part of the fallout cloud passed to the right or to the left of them. Thus, if the problem is merely to move out of the hazardous area, the direction to move will be obvious: cross wind, and away from the center of the cloud path. If the path of the major part of the fallout cloud can not be determined for any reason, the cross-wind direction of least fallout can still be locally determined by (1) radio contact with adjoining units or (2) dispatching a survey unit in either direction. In the latter case, the direction of decreasing radiation rates is the safest movement route. If the survey is made by vehicle, only a few minutes of travel are necessary to make the determination.

If the bursts are very close together or on similar azimuths the problem is the same, and it can also be readily resolved with locally obtained intelligence. In the case where the patterns merge to form a much wider pattern, the best exit path may not be obvious to some units, and additional external intelligence will be required.

The advantage that can be gained, measured in exposure doses, by early movement from a radiologically hazardous area depends on the shielding available at the location, the time of travel required to reach a radiologically safe area, and the shielding available during the period of travel. Earlier movement from the hazardous area will not always result in a minimum exposure dose. For example, take a case where the troops are in foxholes and to reach a fallout free area they must travel on foot for one hour. If fallout cessation is at one hour, the unshielded exposure dose rate at one hour is 100 rad/hr, and the troops start moving out immediately on fallout cessation, their exposure dose, D, would be

$$D = D_{(t_a \rightarrow t_c)} + D_{(t_c \rightarrow t_{c+1})} \qquad (6)$$

where t_a is the fallout arrival time and t_c is the fallout cessation time. If, on the other hand, the troops start moving at t_c + 2 hours, their exposure dose would be

$$D = D_{(t_a \rightarrow t_c)} + D_{(t_c \rightarrow t_{c+2})} + D_{(t_{c+2} \rightarrow t_{c+3})} \quad . \qquad (7)$$

Using a foxhole transmission factor of 0.1 and the appropriate dose rate multipliers and an estimated exposure dose of 3 rad for $D_{(t_a \rightarrow t_c)}$, Eq. (6) becomes

$$D = 3 + (0.5)(0.61)(100)$$

$$= 33.5 \text{ rad}$$

where 0.5(100) is an estimate of the average exposure rate in moving from a 100-rad/hr area to a zero-rad/hr area, and 0.61 is the dose rate multiplier[8] to obtain the exposure dose between t = 1 hour and t = 2 hours. Eq. (7) becomes

$$D = 3 + (0.1)(0.9)(100) + (0.5)(0.19)(100)$$

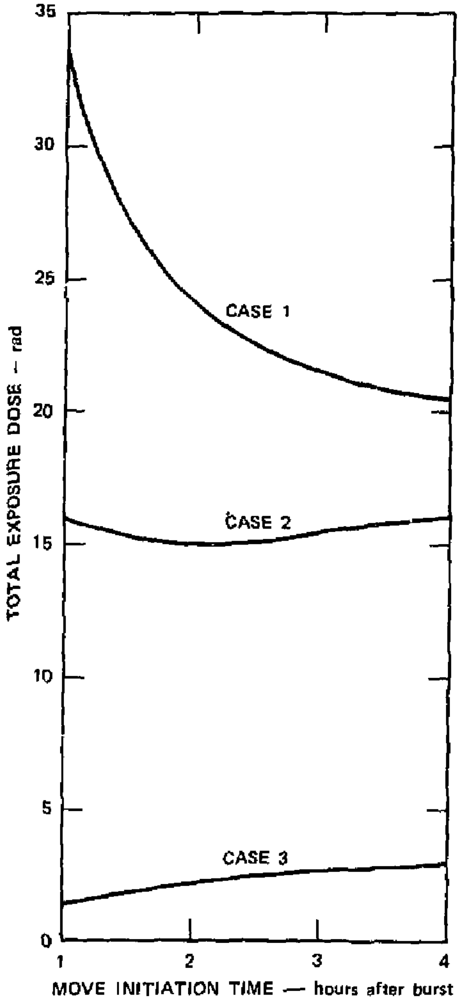
$$= 21.5 \text{ rad}$$

where 0.9 is the dose rate multiplier between t = 1 hour and t = 3 hours, and 0.19 is the dose rate multiplier between t = 3 hours and t = 4 hours. In this example case, the total exposure dose to the troops that moved earlier was about one and one-half times larger than the total exposure dose to those troops that mov-- later. If it is assumed for the same situation that the moves were made in vehicles with a transmission factor of 0.7 and the moving time were half an hour, then the calculated total exposure dose to the troops that moved earlier would be 16 rad and the total exposure dose to the troops that moved later would be 15.5 rad.

In the above two example cases, the radiation shielding at the fall-out location was high compared to that available during movement, and consequently a smaller total exposure dose resulted from the later movement. Where this is not the case, earlier movement would result in a smaller total dose. For example, take the case of personnel in tanks. In this case, let it be assumed that in a bunkered location the personnel in tanks had a transmission factor of 0.02, and that during movement they had a transmission factor of 0.04. For a moving time of half an hour, the total exposure dose to tank personnel that moved earlier (at t_c) would be 1.34 rad, whereas the total exposure dose to tank personnel that moved later (at $t_c + 2$) would be 2.6 rad. The total exposure doses to personnel for the three examples for various move initiation times are shown in Figure 1. As can be seen, even for those troops caught in radiologically hazardous areas, the need to move is not immediate and they can await externally supplied radiological intelligence or movement instructions without exposure dose penalties, provided they are in foxholes or in locations with equivalent shielding. Tank personnel, on the other hand, are not endangered unless the fallout radiation is more than a magnitude higher, and since such fallout areas are relatively small and very close to ground zero, the best direction to move would be obvious soon after the burst.

B. Planned Maneuvers

As used here, a planned maneuver is one where troops in a nonfallout hazardous area are moved to another nonfallout hazardous area without incurring unacceptable exposure doses. If the planned move is only a short distance, the fallout conditions along the possible routes and at the destination can be determined locally; that is, by radio contact with adjoining units or by a scouting sortie. If the planned move is a long distance move, then external radiological intelligence is required. Plans for long moves on the other hand will originate at higher echelons; e.g., division headquarters. In this case, the division headquarters needs to be apprised of the hazardous radiation areas in the battlefield. Although there may be other emergencies making it necessary to start these maneuvers immediately, it is not because of the fallout hazard. The need for the entire radiological assessment system, therefore, is at higher echelons--i.e., division level and above--rather than at lower echelons--brigade level and below.



CONDITIONS:

Unshielded exposure rate at t_c = 100 rad/hr

CASE 1 personnel in foxholes with transmission factor of 0.1; time required for move = 1 hr; transmission factor during move = 1.0.

CASE 2 personnel in foxholes with transmission factor of 0.1; time required for move = 1/2 hr; transmission factor during move = 0.7.

CASE 3 personnel in bunkered tanks with transmission factor = 0.02; time required for move = 1/2 hr; transmission factor during move = 0.04.

SA-2605-4

FIGURE 1 PERSONNEL EXPOSURE DOSES FOR VARIOUS MOVE INITIATION TIMES

For defensive maneuvers, the division should be apprised of the radiological conditions behind the forward edge of the battle area (FEBA). For offensive maneuvers, the division should also be apprised of the radiological conditions beyond the FEBA. Also, the sooner the radiological situation is determined, the sooner the plans can be firmed and the maneuvers executed. The advantage that can be gained by an earlier execution of maneuvers depends on individual battlefield situations.

V CURRENT CAPABILITIES

A. Prediction

As previously stated, the essential nuclear burst information for fallout predictions is: (1) location of GZ, (2) yield, (3) time of burst, (4) HOB, (5) FY/TY, and (6) meteorological data.[5,9] The GZ can be most accurately located if it can be seen by an observer. Where GZ cannot be seen, the distance to the burst is estimated by measuring the "flash to bang time," and the direction is determined by measuring the azimuth of the cloud from the observer location. The location of GZ can also be determined by the intersection of the measured azimuths from two or more observation points. Where the nuclear cloud is obscured from observers, the flash to bang times from several locations can also be used to locate GZ. Multiple bursts, however, could make it difficult to pair up the flashes with the bangs.

The burst yield is estimated by measuring the cloud width at five minutes after burst, the altitude of the cloud base and the cloud top at approximately ten minutes after burst when the cloud has stabilized, and the burst illumination time. The cloud dimensions are based on distance estimates, e.g., flash to bang times, and on angular measurements of the cloud taken with artillery aiming circles or theodolites. Even if the cloud dimensions could be accurately determined, however, the burst yield remains an estimate because a specific cloud dimension could result from yields varying by as much as a factor of ten. The burst illumination time is considered to be an even less reliable measure of yield; however, it is the only measure if the nuclear cloud is obscured because of terrain, weather, or darkness. Even so, multiple bursts could also make it difficult to separate out the illumination times.

Currently, there is no procedure for estimating the HOB. If the nuclear cloud can be seen and a thick dense stem is observed, then a surface burst is reported. If the stem is not connected to the mushroom part of the cloud, an air burst is reported. The planned HOB of weapons detonated by friendly forces, however, will be known.

There is also no way to estimate the FY/TY ratio of enemy bursts. For the smaller tactical weapon bursts, however, a ratio of unity is a good estimate. Currently a FY/TY of one is used for predicting fallout from all enemy bursts.

The meteorological data are provided by the weather detachment of the division staff. The meteorological conditions, however, are at times subject to relatively rapid and unpredictable changes. Also, the fallout airspace of one weapon burst could be disrupted by other nuclear bursts.

The fallout prediction inputs can generally be described as very imprecise. The current fallout prediction model is also extremely simple in concept; with the use of nomographs a manual computation of a fallout prediction can be completed in five minutes.[9] With predrawn patterns for various yields and winds and for various map scales, a pattern need only be selected after the burst data are received. The fallout pattern consists of two symmetrical exposure dose contours. The close-in contour shows where unprotected personnel might receive 100 rad in the first four hours after fallout arrival, and the remote contour represents a dose of 20 rad in the first six hours. The direction of the pattern bisector is the effective fallout wind direction determined from a wind hodograph. The altitude of the nuclear cloud used is either the observed altitude or an estimated altitude for the estimated yield from illumination time measurements. Also, if the effective fallout wind is less than eight km/hr, the fallout contours, instead of being end to end, are two concentric circles around the GZ, where the outer circle radius is twice the inner circle radius and the inner circle radius is a function of yield.

For illustration purposes, the close-in contours of the current prediction model for surface burst yields of 5 kT, 20 kT, and 50 kT are shown in Figure 2 for a sheared wind with an effective speed of 20 ft/s. Also shown in Figure 2 is the 100 rad/hr standard intensity contour obtained by SRI's SEER MODEL[10] for a 20-kT burst. The four-hour exposure dose for the 100 rad/hr standard intensity contour is estimated to be approximately 100 rad. As can be seen, there are significant differences in the patterns. Also of importance is the fact that current prediction capabilities do not include rainout or washout radiation pattern predictions.

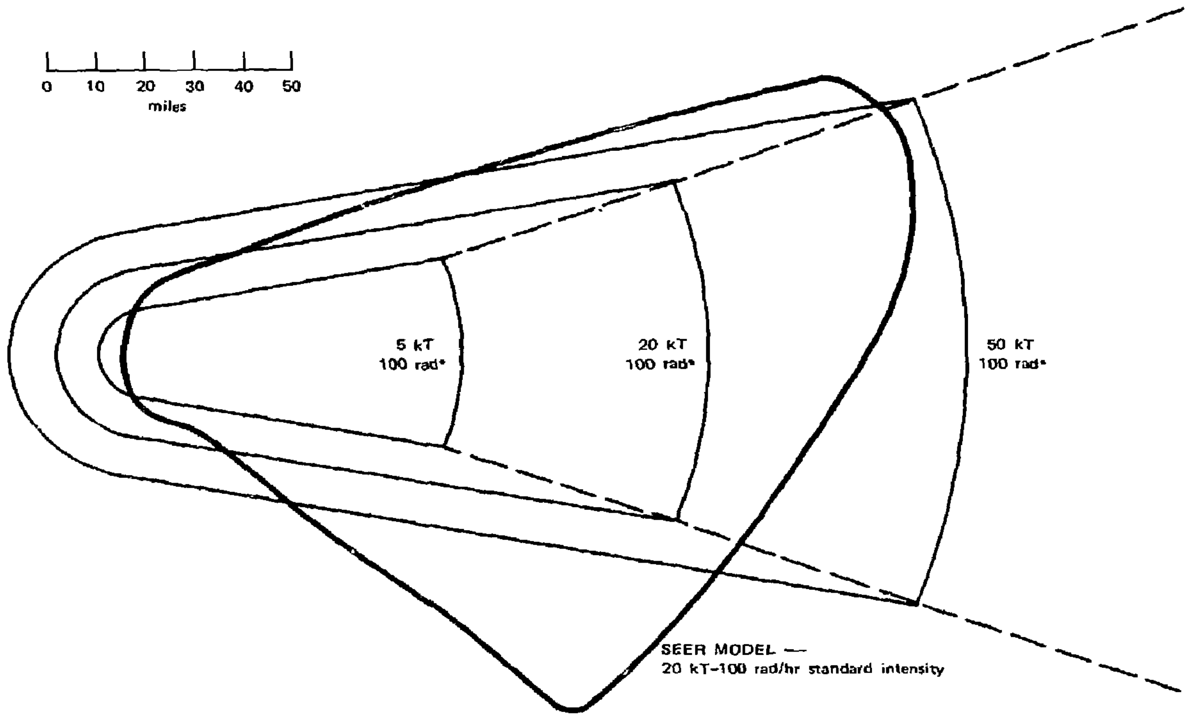
B. Monitoring

Radiological monitoring, whether periodic or continuous, is conducted by those units that are issued radiacs. The monitoring data is limited to the measurement of radiation at various times at whatever locations the monitoring units are at the time of the measurements. The radiac for this purpose (also used for radiological surveys) is the IM-174A/PD. The specifications of this instrument, shown in Figure 3, are as follows:[11]

Range:	1 rad/hr to 500 rad/hr
Dimensions:	6-3/4 x 4-1/4 x 4-3/4 in.
Weight:	4 lb 2 oz

The designated number of these instruments allotted per battalion depends on the type of battalion; e.g., 23 per tank battalion and 30 per mechanized infantry battalion.[12] The allotment per mechanized infantry rifle company is seven. A mechanized infantry division is allotted about 500 IM-174A/PD radiacmeters.

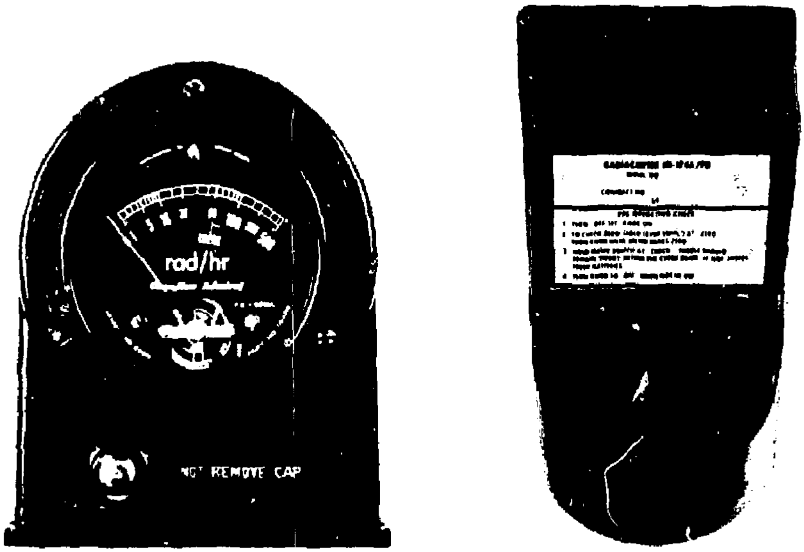
Monitoring for radiation is conducted by company/troop/battery units (or smaller units operating independently) after nuclear operations have commenced. All units routinely monitor a designated point in their unit area periodically at least once each hour. Continuous monitoring is



*Dose received in first four hours after arrival of fallout.

SA-2605-5

FIGURE 2 COMPARISON OF PREDICTION CONTOURS



(TOP) (FRONT)

SOURCE: Reference 13.

SA-2605-6

FIGURE 3 IM-174A/PD RADIACMETER

commenced when a fallout warning is received, after indications of a nuclear burst in the vicinity, during movement, or when radiation above 1 rad/hr is detected.

Radiation monitoring techniques may be direct or indirect. A direct measurement is taken in the open, clear of objects that can shield out part of the radiation, with the radiacmeter one meter from the ground (about waist-high). Indirect measurements must be used if safety considerations dictate. Indirect measurements may be taken inside vehicles or inside shelters. Indirect measurements must be converted to unshielded readings by means of a correlation factor, determined by taking a reading inside the shelter and then immediately taking another reading outside the shelter. If it is unsafe to leave the vehicle or shelter to take an outside measurement, the correlation factor is assumed to be approximately the inverse of the transmission factor shown in Table 1 for the type of shielding available for the indirect measurement. For example, a radiacmeter measurement of 5 rad/hr in a foxhole would correspond to an outside measurement of 50 rad/hr (transmission factor = 0.1, correlation factor = 10).

Automatic reports of monitoring measurements in a division area are submitted by voice radio through command or intelligence channels to the division tactical operations center (TOC) where they are processed by the chemical-biological-radiological element (CBRE).* The CBRE prepares fallout dose-rate contour charts and issues warnings of radiological contamination and hazardous areas based on collation and analysis of these reports. At the present time CBRE processing is entirely manual.

Fallout dose-rate contour plotting requires an adequate number of monitoring reports from locations distributed throughout the contaminated area. An analysis performed at the Livermore Radiation Laboratory has shown that with adverse wind conditions if the interval between radiological dose-rate monitoring stations exceeded 3.2 km, the pattern of a 20-kT weapon might be difficult to distinguish. Radiological monitoring is performed at the company and battery levels, so that the distance between monitoring points corresponds to the distance between company sized units. An analysis of an Army-developed defensive deployment (set in Europe), which was based on FM 100-30 (TEST), showed that the average

*The CBRE operates the NBC center previously mentioned.

intercompany distance was 4.4 km.* The distribution of intercompany distances was:

Distance (km)	Percentage of Cases
3.6 - 4.0	18%
4.1 - 4.5	43
4.6 - 5.0	26
5.1 - 5.5	13

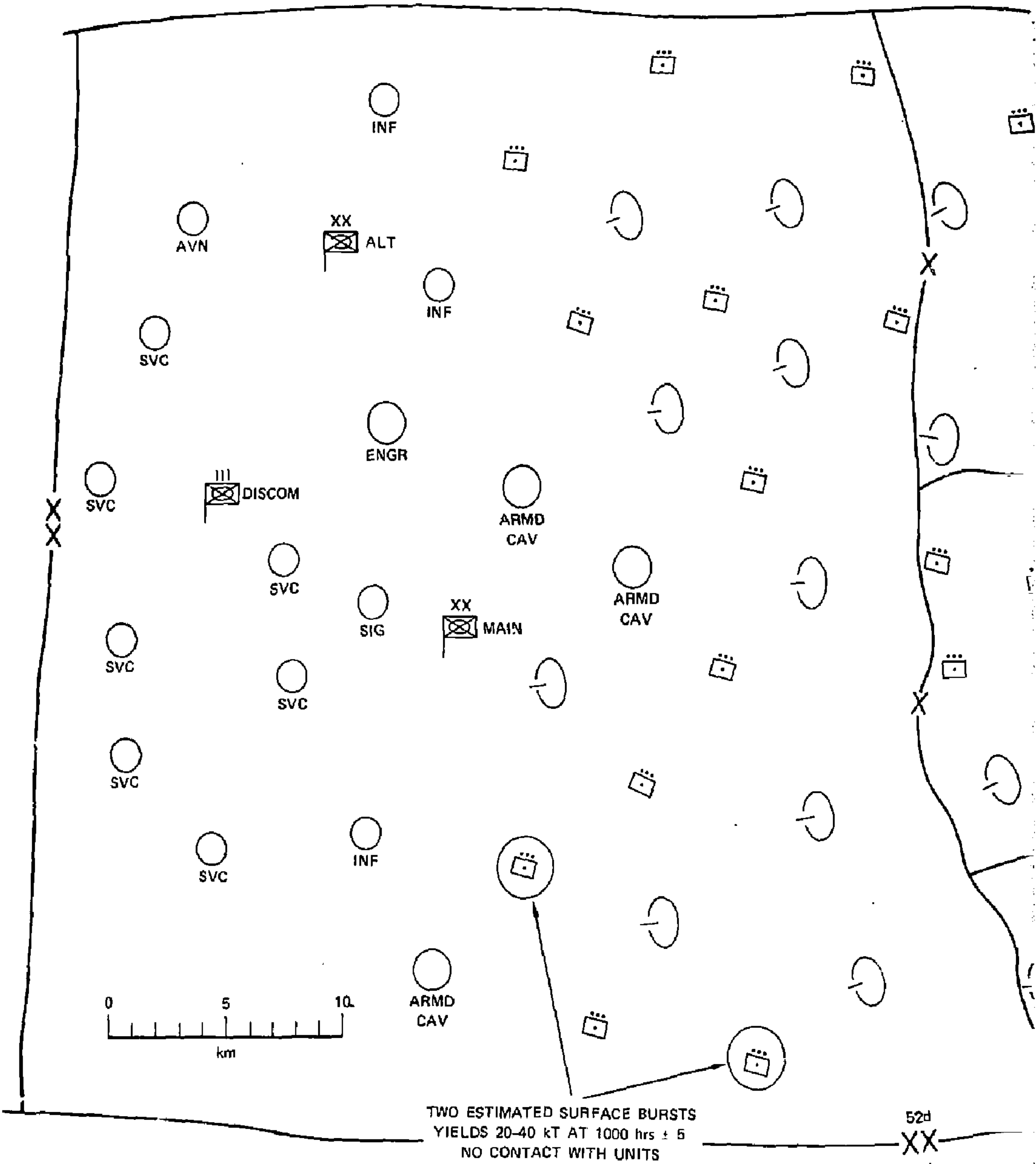
An Army division in a tactical nuclear warfare deployment has an area of responsibility with a frontage of 36-50 km and a depth of 60-80 km. Hence, the average size of the division's area of responsibility is about 3000 square kilometers. Within this area there are 293 squares with 3.2-km sides, or 155 squares with 4.4-km sides. A division is now allocated about 500 radiological survey meters, IM-174A/PD, that measure gamma radiation in the range of 1 to 500 rad/hr. These meters are not uniformly distributed throughout the division area. Instead, they serve the approximately 109 company-sized units in the division, and they are generally located within 1.5 km of the company headquarters. In a nuclear deployment, company-sized units dispersed with an average distance between them of 4.4 km will occupy only about 70 percent or less of the division area. To have complete radiological monitoring of that 70 percent, it appears that each company should be responsible for reporting at least two positions in gaps between it and adjacent units. In addition, complete monitoring coverage of the remaining 30 percent of the division area would require monitoring at about 90 other locations in the division

*The minimum separation between units for maximum protection (a high degree of assurance that significant casualties will not occur within adjacent units from a single weapon attack) from the effects of a 30-kT weapon is 4.06 km.

area. Consequently, about 300 locations would have to be monitored in addition to the locations in the areas occupied by company-sized units in order to ensure that adequate information be obtained for accurate plotting of dose-rate contours over the entire division area.

In an attempt to assess whether or not current Army doctrine for monitoring fallout would provide sufficiently detailed data, a scenario was developed of a hypothetical attack against deployed U.S. forces. As a basis for the scenario, a request was made to the U.S. Army Command and General Staff College (USAC&GSC) to provide a lesson plan dealing with fallout. They cooperated and sent a complete copy of a lesson on "Tactical Operations in the NBC Environment" (M1306-2, R1306-2).[14] The lesson plan included an overlay showing the forward brigades of a U.S. mechanized division deployed in accordance with the doctrine enunciated in FM 100-30 (TEST).[1] The forward brigades were dispersed into company sized islands of tank and infantry elements, and the artillery was dispersed by platoon. To provide protection against dual unit targeting with a 30-kT weapon, the average interval between forward elements (companies and platoons) was slightly in excess of four km. To create a complete picture, an SRI analyst who was formerly an instructor of the USAC&GSC deployed the balance of the division in consonance with the same doctrine.

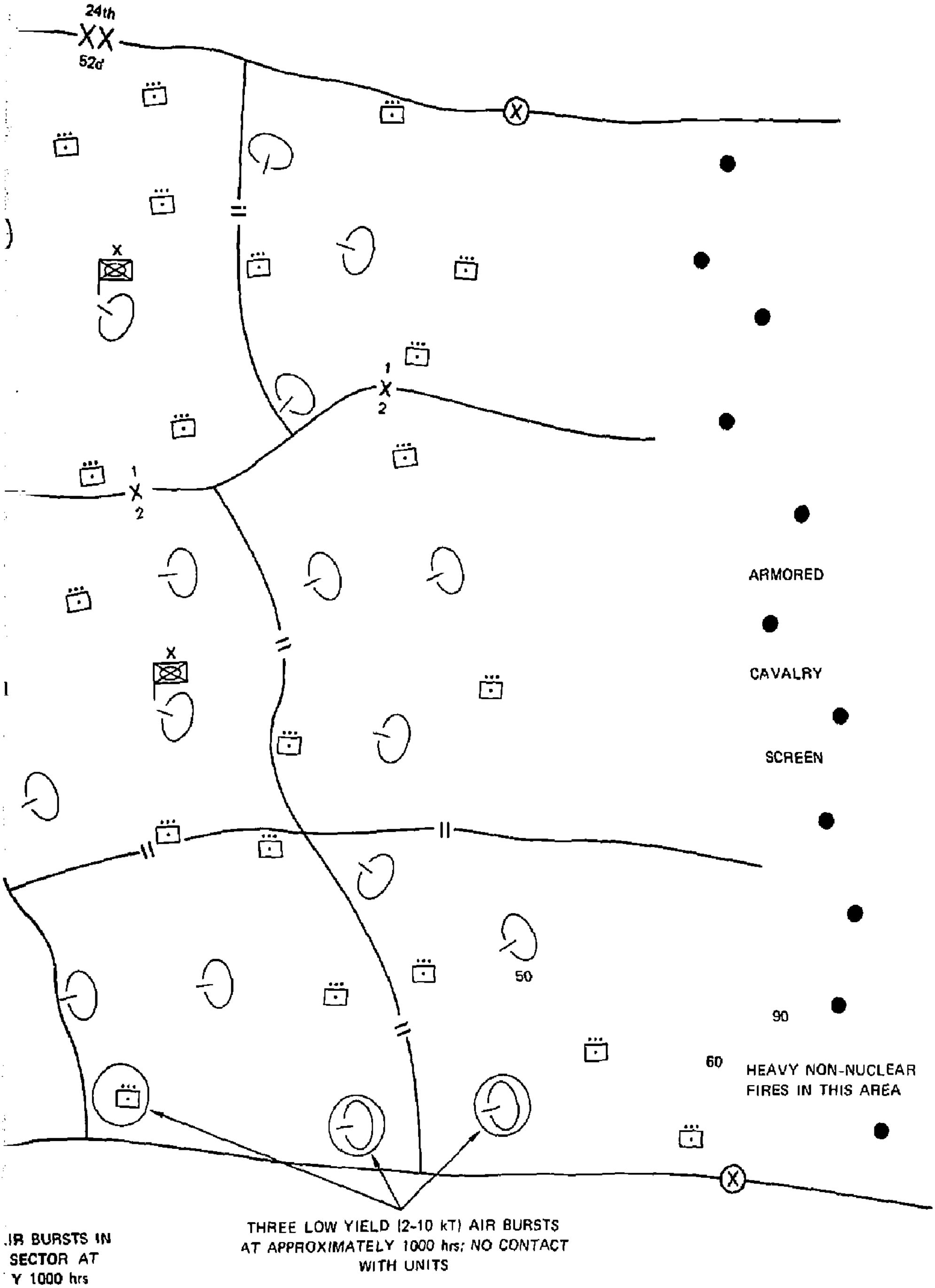
A hypothetical attack was devised, which fell mainly against the division to the south of the division portrayed in the scenario. Some four to six low yield air bursts hit forward defense units in the division on the south. In the sector of the division examined in the scenario, three low yield air bursts were delivered against and destroyed three of the forward defending units on the south flank of the division, and two 20-kT surface bursts were delivered against two nuclear delivery units also in the southern part of the sector. Simultaneously, intense conventional fires struck the armored cavalry unit that was screening forward of the division defense position. This situation is shown in Figure 4.



Infantry or Tank Company in Defense

Field Artillery Platoon

See glossary for meaning of abbreviations.



SA-2605-3R

FIGURE 4 BASIC DEPLOYMENT

Using SRI's SEER model,* fallout patterns were generated for the two 20-kT surface bursts for two quite different winds. The first wind was comparatively slow at the lower levels, very fast at the top level, and had a considerable amount of shear. The second wind had quite high velocity at most altitudes and was fairly consistent as to direction. Using these patterns, overlays were developed that showed the readings that would have been measured at company or platoon centers one hour after the detonation. A second overlay was prepared showing readings that would have been measured at two hours after the detonation for both winds and three hours after detonation for the first (slower) wind. These overlays with the readings made at company or platoon centers were given to four test subjects who were required to plot dose rate contours. Only one of the test subjects had ever plotted fallout dose rate contours before. The task was not easy, because the fallout patterns from the two surface bursts merged markedly in the case of the first wind and had significant overlap in the case of the second wind. The one subject with prior experience took about ten minutes per pattern. The inexperienced subjects took from 20 to 90 minutes--usually a longer time on the first one they did. Surprisingly enough, the dose rate contours prepared by the test subjects did not vary greatly from the actual resultant pattern (developed by superimposing patterns generated by the model).

Patterns prepared by the test subjects would have been adequate to determine which units would have to move, which units it would be desirable to move, and which units should be warned of the impending arrival of fallout. Because all of the units that were subjected to radiation hazard were behind, or near the rear of, the brigade sector, it was

---

*The SEER model produces fallout patterns that are similar to those produced by the DoD DELFIC model for the same inputs. DELFIC is currently the most advanced and sophisticated fallout model in existence.[15]

assumed that performance of their mission did not preclude movement if the hazard warranted. Figures 5 and 6 show the fallout patterns developed by two of the test subjects for the two wind conditions described above, the actual fallout pattern based on the model, and the escape routes selected for units moving out from the fallout zone. At the end of each escape route is a number that represents the dose that would have been accumulated if the evacuating unit had remained in foxholes for one hour after the onset of fallout and then had moved out in armored personnel carriers (APCs) or self-propelled guns. It is worthy of note that the fallout from two 20-kT weapons made it essential for seven units to move and desirable for three units to move for both winds--there was, of course, a difference as to which units were in danger with the two winds. Although not shown on the figures, one subject was asked to select safe routes for moving two armored cavalry troops and a tank company (all in reserve in the division rear) to blocking positions several kilometers south of where the surface bursts occurred. The routes he selected were safe from fallout.

It is worth noting that, once the units in jeopardy evacuate, there will be an area of about 250 square kilometers with no monitoring stations. This suggests the need for "leave behind" radiac instruments that can report automatically (see Section VII).

One deployment, two winds, and the merging patterns from two simultaneous surface bursts (both of the same yield) certainly does not provide a representative sample of what might happen on a nuclear battlefield. However, the results obtained suggest that in many cases the current scheme for performing monitoring at or near company (and artillery platoon) centers could provide adequate assessment data. Whether or not the data could be processed through communications channels, plotted, and converted to dose rate contours in a timely manner is questionable. The basic spot

TWO 20-kT BURST PATTERNS AT H + 3 hours

——— Test Subject

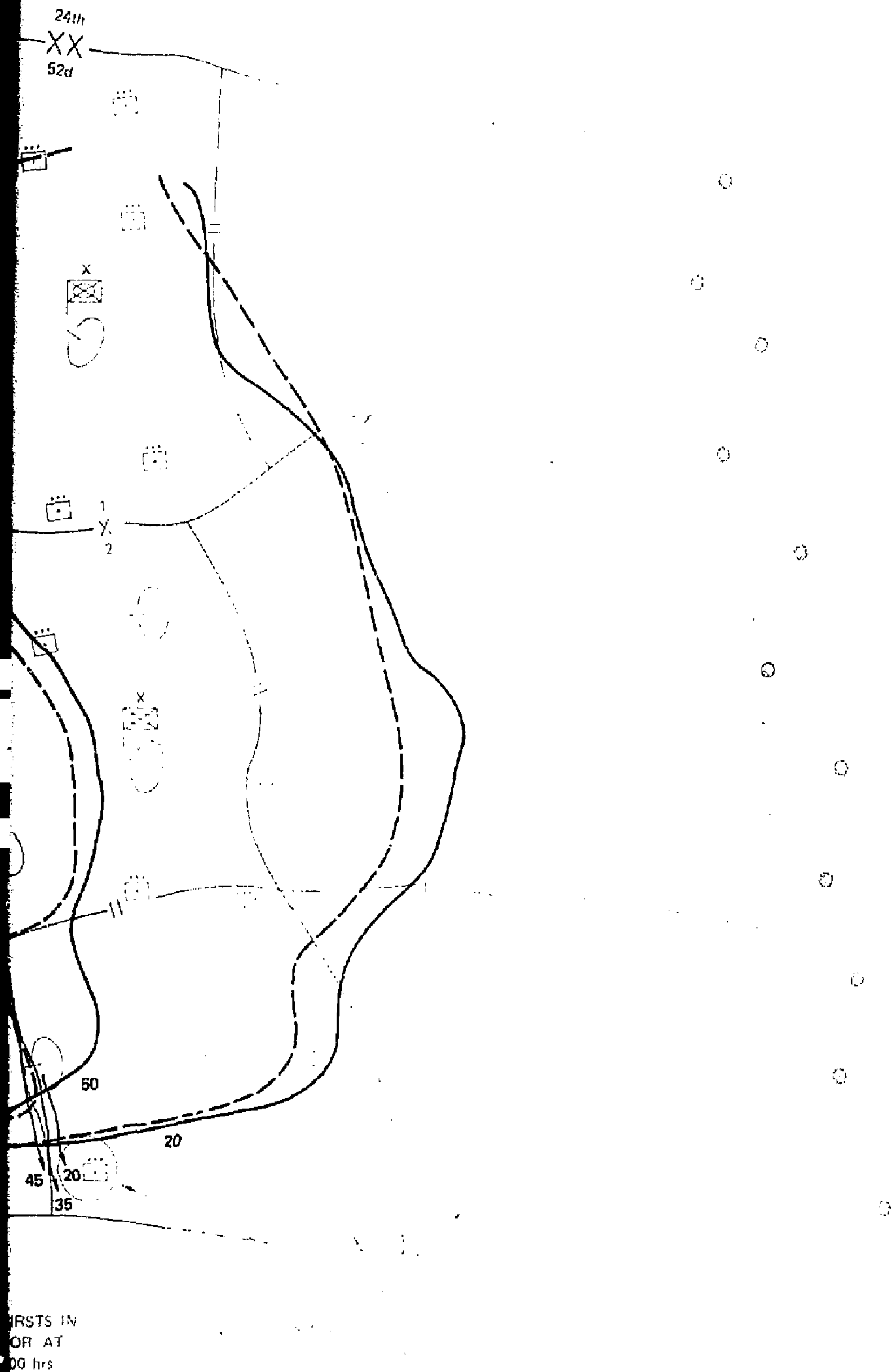
— — · — Approved Solution

4-6 LOW YIELD AIR BURS
54TH MECH DIV SECTOR
APPROXIMATELY 1000

Infantry or Tank Company in Defense

Field Artillery Platoon

See glossary for meaning of abbreviations



2

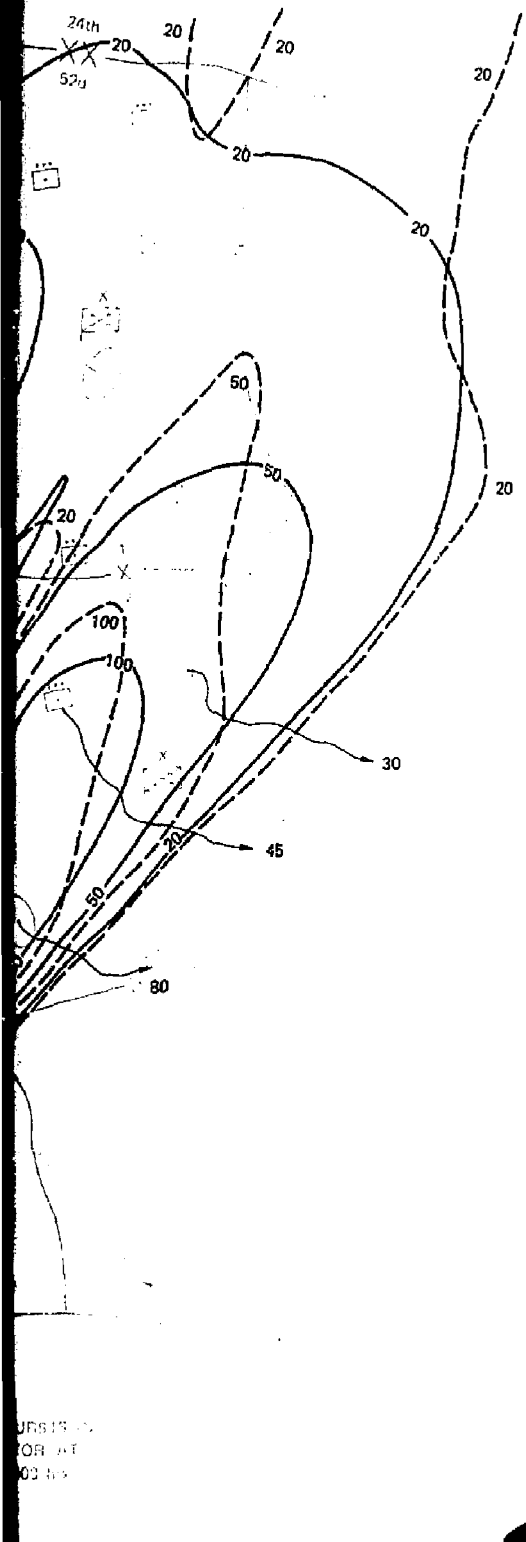
SA-2805-1R

FIGURE 5 FALLOUT PATTERNS AND ESCAPE ROUTES: FIRST WIND CONDITION

TWO 20-kT BURST
PATTERNS AT H + 2 hours

—— Test Subject

– – – Actual



SA-2605-2R

2

FIGURE 6 FALLOUT PATTERNS AND ESCAPE ROUTES: SECOND WIND CONDITION intensity readings (from companies or platoons) given our test subjects for the first wind at H + 3 would have required the processing of at least 51 reports through communications; typically, each report would have had to pass through two intervening echelons to reach the division. The manual recording and plotting of these spot readings at the division NBC center would consume significant time. Then, the manual preparation of dose rate contours, as previously indicated, would take from 10 to 20 minutes, or more. Considering that these actions would be taking place in a rather chaotic environment, it is estimated that the dose rate contours would be between one and two hours old by the time they were reproduced and distributed (see Section VII). It is questionable whether a two hour old dose rate pattern would have much operational utility.

C. Radiological Surveys

Radiological surveys are conducted only when essential radiological contamination data cannot be obtained from monitoring reports by units within the contaminated area.[5] The personnel in a chemical, biological, and radiological element (CBRE) of a division tactical operations center (TOC) analyze incoming monitoring data, determine its adequacy, and recommend a survey if they deem it to be required. They also direct the activities of the survey parties, which report directly to the CBRE control party. The CBRE may also request that a subordinate unit be directed to conduct a survey. In this case, the subordinate unit control party will plan and direct the survey, check the data, and transmit the data through channels to the division CBRE. The constraints on radiological survey operations are (1) the time available for the survey, (2) personnel exposures, and (3) area accessibility.

1. Ground Surveys

Ground radiological surveys are normally performed by personnel in wheeled or tracked vehicles. Armored vehicles are preferred because of the additional personnel shielding they provide. The ground dose rates can be determined by the use of a correlation factor with the readings taken within the vehicle. The ground survey rate (performed by personnel in vehicles) is estimated to be from 15 to 40 square kilometers per hour per vehicle, depending on the detail required and the terrain. Although the rate per vehicle is relatively slow, several vehicles with accompanying personnel could be employed on the task. Ground survey capabilities, however, are limited to battlefield areas under the control of friendly forces.

2. Aerial Surveys

The advantages of aerial surveys over ground surveys are speed and flexibility; however, aerial surveys are less accurate. Accuracy is increased with slower air speeds and lower flying altitudes. Air-ground correlation factors are used to estimate the ground dose rates. The aerial survey rate is estimated at between 130 and 450 square kilometers per hour per aircraft. Whereas aerial surveys have time, personnel exposure, and accessibility advantages, they also have disadvantages (besides inaccuracy). For one thing, unless fallout is complete, the airborne activity and aircraft contamination could affect the radiac readings considerably--leading to erroneous estimates of ground dose rates. A slow, low flying aircraft is also very vulnerable to enemy fire. Although current doctrine limits aerial surveys to areas under friendly force control, it appears that aerial sorties for radiological data over enemy territory would be feasible under some circumstances.

D. Communications

The current communications capability of a division is more than adequate to support the reporting of nuclear bursts, fallout monitoring data, and radiological survey data. For example, the following is a partial list of the radio networks (voice unless otherwise indicated) that exist at the following:

- Rifle Company
  - Command net--links the commander with each platoon leader and antitank squad leader.
  - Fire direction (FD) net--links each of three forward observers with the company fire direction center (FDC).
- Infantry Battalion
  - Command net--links the commander and his key staff officers with all company commanders.
  - Logistics net--links battalion S4 and the executive officer with all company commanders.
  - Surveillance net--links S2 with all surveillance radars (5), which are normally deployed with the rifle companies.
- Direct Support Artillery Battalion (supports brigade)
  - Fire direction (FD) nets (3)--links fire direction center with each battery (3), each maneuver battalion liaison officer (3), and each forward observer (9).
  - Command and fire direction (F) net--links the battalion commander with the liaison officer at the brigade, each battery commander (3), and each liaison officer who is with a maneuver battalion (3).
- Brigade
  - Command net--links the commander and his key staff officers with each battalion commander and battalion S3.
  - Logistics net--essentially the same as the command net, with different key staff officers.

- Division
  - Area communications system (voice, teletype, data, facsimile)--a microwave multichannel system that links the division signal center with area signal centers, which in turn tie into brigades, division artillery, and separate units.
  - Division command net--links the commander and G2/G3 with brigades, division artillery, and all separate units.
  - Division operations/intelligence net [radio teletypewriter (RATT)]--generally the same as the command net.

The flow of reports and warning concerning nuclear strike effects is shown schematically in Figure 7. These reports and warnings are contained primarily in the following five NBC reports, which are transmitted over the above networks within the division area:[13]

NBC 1. Report used by the observing unit to give initial and subsequent data of a nuclear attack.

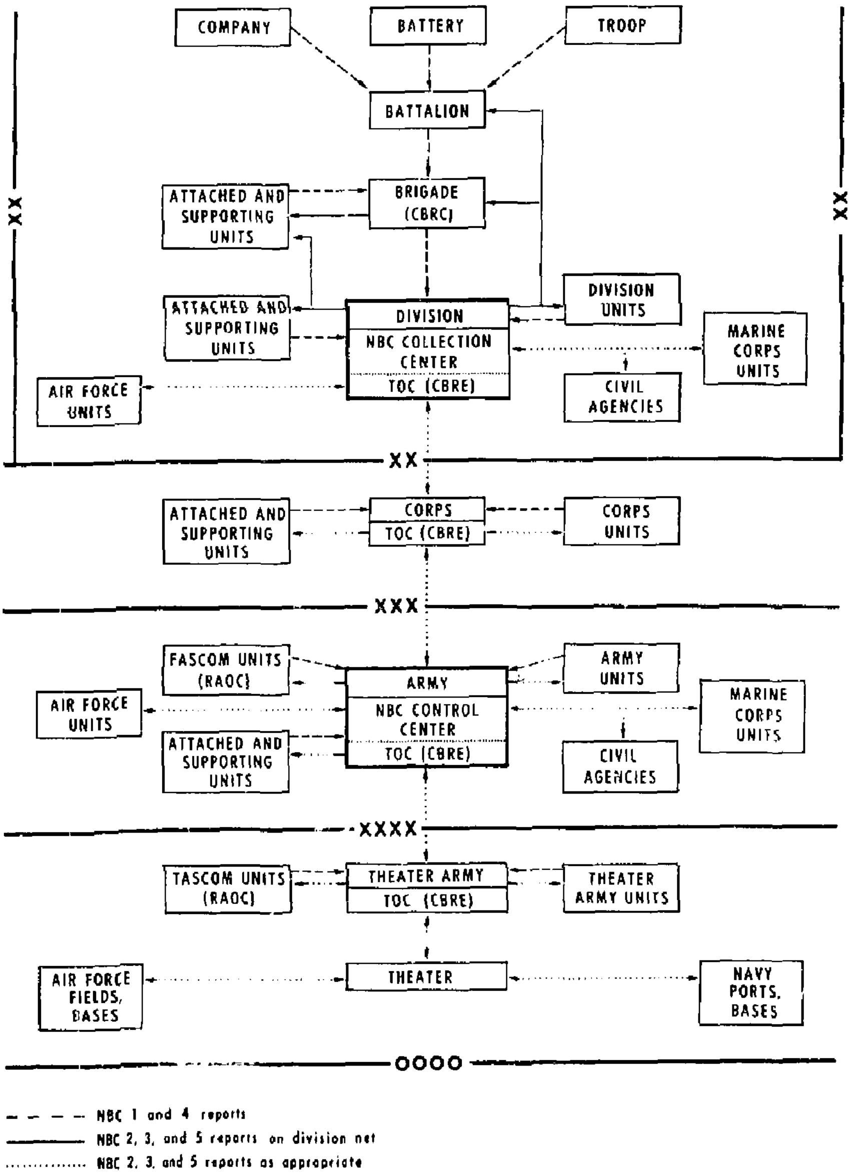
NBC 2. Report used for passing evaluated data of a nuclear attack.

NBC 3. Report used for warning of expected radiological contamination or hazardous area.

NBC 4. Report used for radiation dose rate measurements.

NBC 5. Report used to locate the area of radiological contamination or hazard.

Figures 8 and 9 depict the schematic flow of nuclear burst reports (NBC 1 and NBC 2) in the division and identify radio nets used in reporting. These reports originate with artillery and mortar units equipped with aiming circles and able to take relatively accurate measurements of burst parameters. Figure 9 also shows the flow of NBC 4 reports of radiation dose rate measurements if those units equipped with aiming circles are disregarded. Figure 10 illustrates the typical flow of dosimetry information in the division; however, this type of information, although very important for tactical operations of units in a nuclear environment, is not covered by the NBC reports.



SOURCE: Reference 13.

SA-2605-7

FIGURE 7 SCHEMATIC ORGANIZATION FOR REPORTING ENEMY NUCLEAR ATTACKS AND WARNINGS OF RADIOLOGICAL HAZARD AREAS

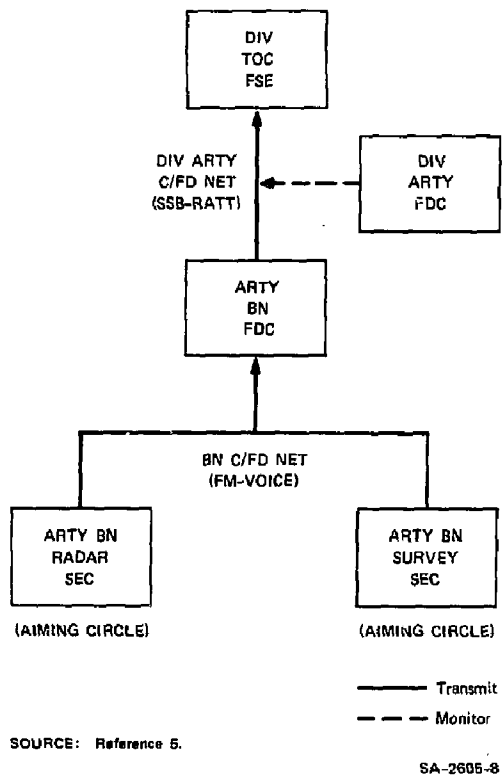
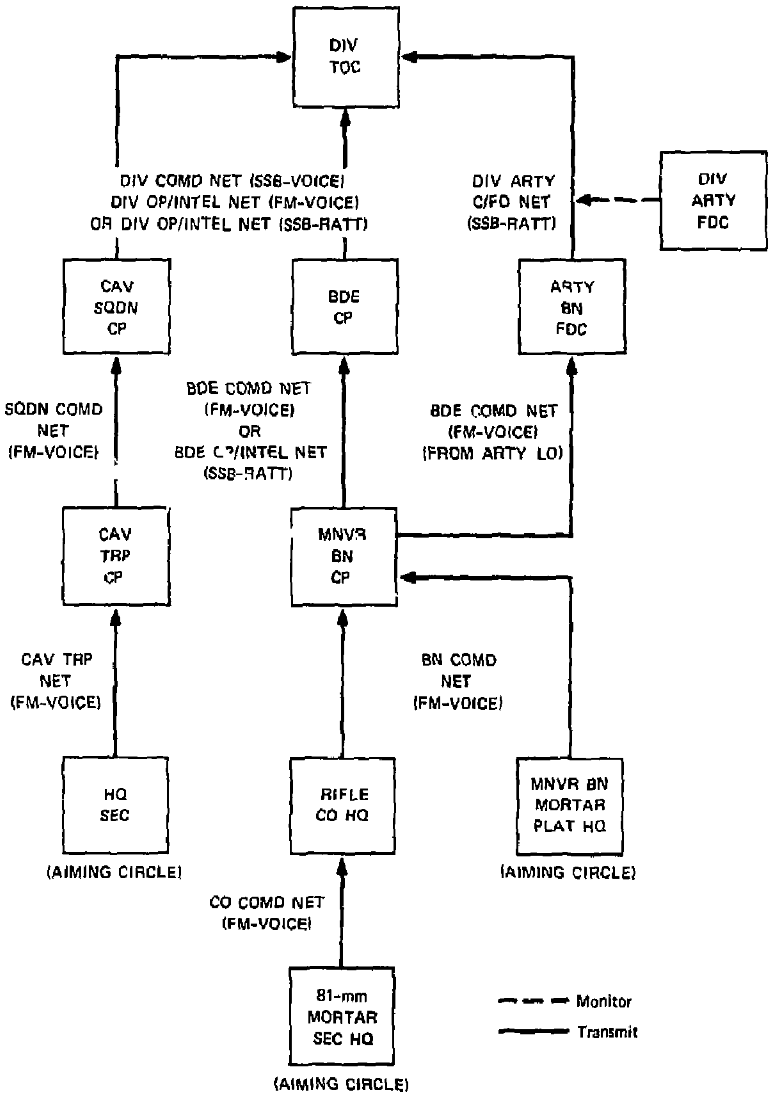


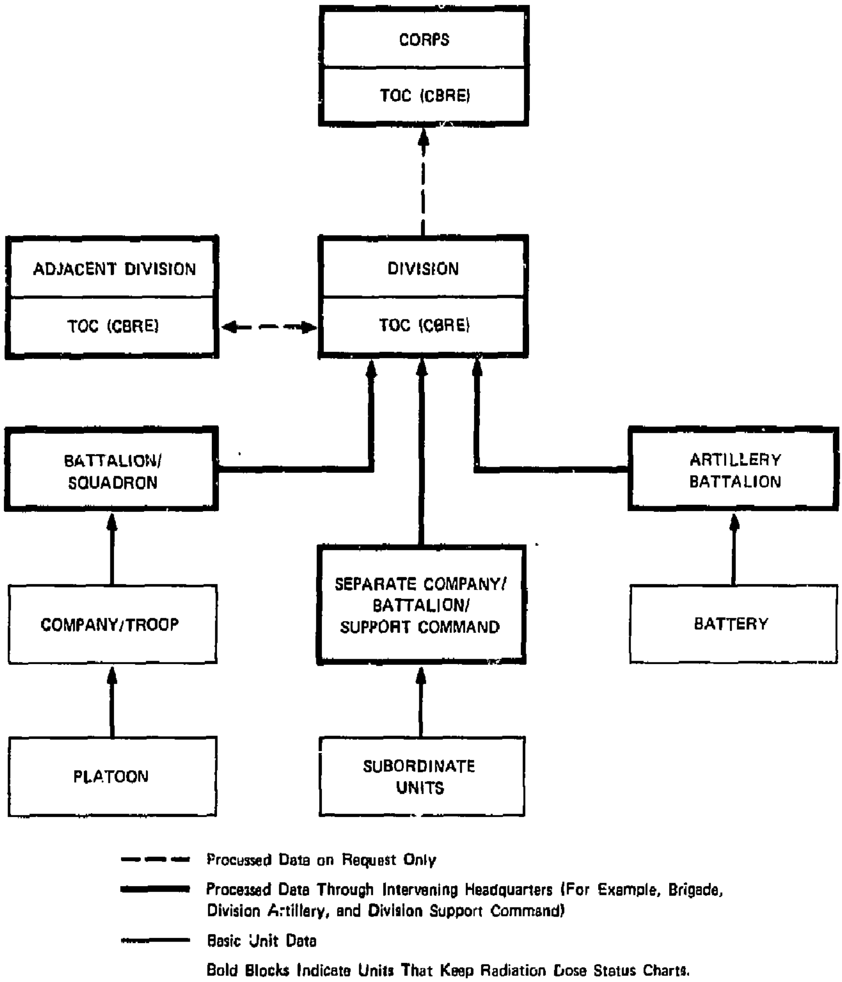
FIGURE 8 SCHEMATIC FLOW OF NUCLEAR BURST DATA IN THE DIVISION: PRIMARY COLLECTION UNITS (GROUND OBSERVATION)



SOURCE: Reference 6.

SA-2605-9

FIGURE 9 SCHEMATIC FLOW OF NUCLEAR BURST DATA IN THE DIVISION: ALTERNATE COLLECTION UNITS (GROUND OBSERVATION)



SOURCE: Reference 13.

SA-2605-10

FIGURE 10 TYPICAL FLOW OF UNIT DOSIMETRY INFORMATION WITHIN THE DIVISION

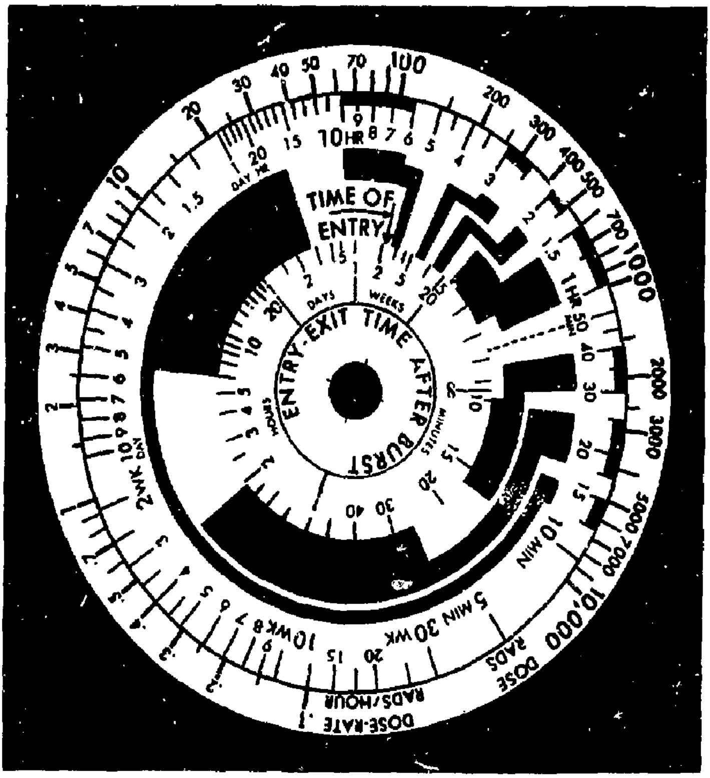
E. Data Processing

The division chemical officer and his section (three officers and seven enlisted men) are responsible for manning and operating the Chemical Biological and Radiological Element (CBRE) of the division Tactical Operations Center (TOC). The CBRE analyzes nuclear burst and monitoring data, plans surveys, analyzes survey data, maintains a radiological situation map, disseminates contamination data, and maintains the radiation status of subordinate and attached units.

Before nuclear employment the CBRE must be aware of division unit deployments, the battlefield terrain and routes, and current operational plans. During this period, the CBRE receives current wind data and updates fallout wind vector plots. This activity is continued after a nuclear burst; the CBRE then has the additional duties of receiving and maintaining burst data and plotting fallout predictions. Also, where the reported nuclear burst data from assigned reporting units are incomplete, the CBRE may request nuclear burst data from other field units. The planning of radiological surveys is also initiated at this time. Later, as radiological monitoring data become available, these data are received, processed, and maintained. Data processing and data maintenance includes data point mapping, determination of radiological decay, preparation of radiological dose rate and dose overlays, and keeping this information current. It is also at this time that radiological survey plans are completed and the survey operations are directed. On receipt of the survey data, they are integrated with the previously obtained burst and monitoring data and processed to correct, add to, and update the dose and dose-rate overlays. The CBRE is also responsible for maintaining the radiation status of subordinate and attached units, and is required to disseminate radiological contamination data.

Data processing at the CBRE is accomplished manually. The calculation aids include mathematical tables, charts, nomograms, and the ABC-M1 calculator. This is shown in Figure 11; it is a circular slide rule designed for radiological calculations.

It can be anticipated that while the CBRE is engaged in data processing for nuclear bursts that have already occurred, other bursts may occur that would interrupt ongoing data processing and other activities. Also, simultaneously, division units will be engaged in defensive or offensive maneuvers. In a fast changing situation, it is acknowledged that the prescribed detailed manual data processing could be too time



SOURCE: Reference 5.

SA-2605-11

FIGURE 11 ABC-M1 CALCULATOR

consuming, and that various rough estimates may be necessary to supply the radiological information when it is urgently needed. The activities of the CBRE at the TOC for fallout bursts at the rate of one per hour are shown in Figure 12. An increased nuclear tempo will result in increased overlapping of activities.

F. Summary of Current Capabilities

The current radiological assessment capability resides in three data acquisition capabilities (fallout prediction, radiation monitoring, and radiological surveys), a communications capability, and a manual data processing capability. Data acquisition, communications, and data processing are the elements that constitute the radiological assessment system where all three elements are essential for the system to function.

In a fast moving nuclear battle situation, the speed with which radiological data are acquired, analyzed, and the results disseminated could affect the outcome of the battle significantly. Fallout prediction from nuclear burst data will be the earliest radiological information that can be made available, but the current prediction capabilities are very limited and the predictions are too inaccurate and unreliable for the commitment of operations. Monitoring data are the next type of radiological information that will become available after each fallout producing nuclear burst. It is anticipated that the monitoring data in some but not all cases will be sufficient input for radiological analysis. The elapsed time from nuclear burst to acquire and process monitoring data and to disseminate the resulting radiological intelligence would, in some cases, be too long to be operationally useful. Finally, if the burst data and the monitoring data are found to be inadequate for determining radiological conditions, radiological surveys will be implemented. In this case, the time needed to acquire and process the survey data and to disseminate the resulting radiological intelligence will be even longer.

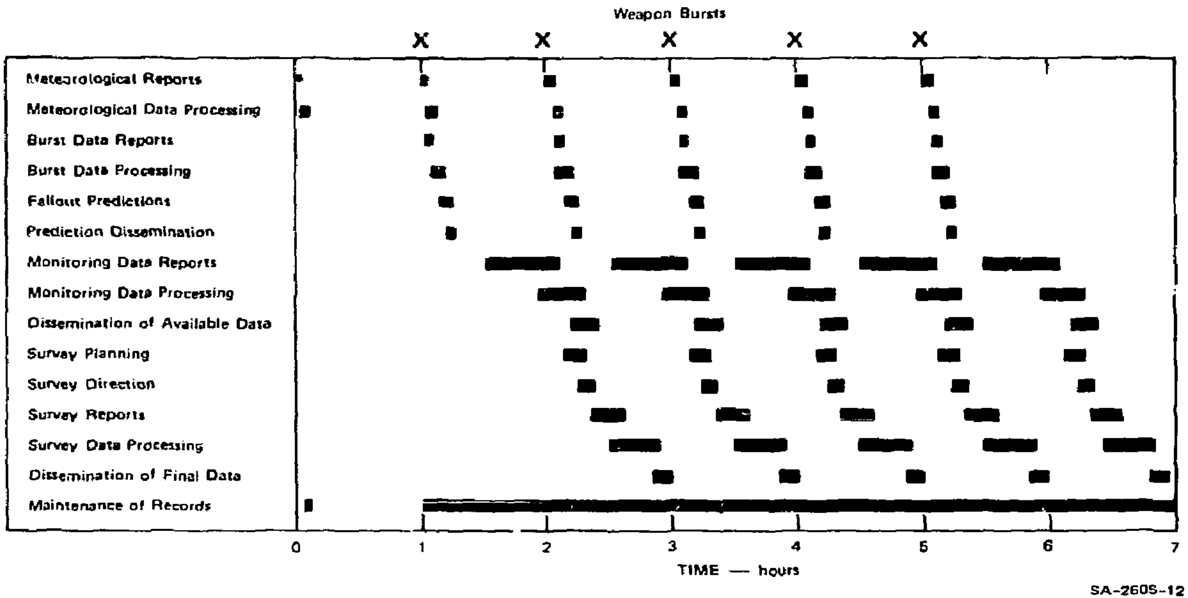


FIGURE 12 CBRE ACTIVITIES FOR ONE FALLOUT BURST PER HOUR

The time consuming elements in the radiological assessment system are voice transmission of nuclear burst and radiological data, the fallout deposition time, the time required to conduct radiological surveys, and data processing.

Questions regarding the services' evaluation of the adequacy of current doctrine, the adequacy of the current battlefield radiological hazard assessment capability, and the current readiness of military units in the field to respond to a tactical nuclear engagement were not resolved. A questionnaire was prepared to obtain this information; it is attached as Appendix A to this report. It is believed that adequate response to the questionnaire can be obtained only through military channels and only then if it is accompanied by a directive to respond. The fact that the military are seeking improved systems and system components, however, is an indication of their evaluation of current battlefield radiological hazard assessment capabilities.

From the few interviews conducted, there was a consensus that for a nuclear battle where the nuclear bursts are predominantly air bursts, the current assessment system is adequate, the doctrine is adequate, and the service units are adequately ready to respond accordingly. There was also a consensus that there was room for system improvement and doctrine improvement.

There was concern that the current system would be inadequate in the event that a greater percentage of bursts with contaminating fallout occurred; however, the generally unanimous opinion that air bursts would predominate indicates that bursts with contaminating fallout are not generally anticipated. Yet there are no guarantees that surface bursts will not be used when they can be applied to tactical advantage; for advantage, to deny the opponent access to certain terrain. Furthermore, even if the entire battle is fought with air bursts, the radiological hazards on the battlefield could be of major significance if the nuclear debris from the air bursts was subjected to rainout or washout. This possibility, rather than being remote, is all too likely to occur. For example, the frequency of precipitation occurrence in Germany is extremely high. It can be summarized as follows: Spring, 25 days per month; Summer, 23 days per month; Fall, 24 days per month; Winter, 26 days per month.* Also, the frequency per day on precipitation days averaged about two periods per day with an average duration of about two hours.

The point is that the probability that a tactical nuclear battle will include a significantly large percentage of radioactive contaminating events is sufficient to warrant greater concern for improving the current radiological hazards assessment capabilities. Whereas the adequacies and inadequacies of the current assessment system have been discussed for specific conditions along with various suggested system component improvements, overall system evaluation remains unresolved. The principal difficulties are that the range of possible battlefield events and conditions is large and the probability on any occurrence is not known. A suggested conceptual system evaluation procedure for providing guidance on overall improved system selection is attached as Appendix B.

---

* SRI rainout research currently in progress, based on analysis of data by the U.S. Air Force Environmental Technical Applications Center.

VI FUTURE DEVELOPMENTS

A. Improvement Areas

As indicated in Section V, the current battlefield radiological hazard assessment capabilities reside in three distinct systems: radiological fallout prediction, radiological fallout monitoring, and radiological fallout surveys. All three systems can be separated into a sensing component, a communications component, and a data processing component. Associated with each system are capability and operational requirements; these can be expressed in terms of reliability, accuracy, vulnerability, time, equipment, manpower, and personnel exposures. The improvement of battlefield radiological hazards assessment capabilities, therefore, could be served by improving one or more systems in any one of the areas cited.

With regard to the three distinct current systems, if the prediction system could be developed to produce reliable and accurate predictions, it would be superior to a monitoring system or a survey system. It would be superior because whereas monitoring and surveys must await the cessation of fallout, predictions could be made before the fallout event--allowing time for countermeasures and, in general, earlier radiological intelligence. If the prediction system cannot be adequately improved, then the primary candidate system for improvement is the monitoring system. An adequate monitoring system will supply the needed radiological data faster than a system that requires radiological surveys. It would be prudent, however, to make improvements in the survey system as well as the monitoring system, since they complement each other when the coverage of the monitoring system is inadequate.

With regard to the components of a system, improvement of the sensing component could be in the areas of increased coverage, increased speed, increased accuracy, and decreased vulnerability. Communications improvement could be in the areas of increased speed and decreased vulnerability. Data processing improvement could be increased accuracy, increased speed, and decreased vulnerability. Increased data processing accuracy for the prediction system could include a better fallout prediction model.

With regard to equipment, improvements could include increased versatility, increased accuracy, increased automation and speed, increased miniaturization, and decreased vulnerability. The operations associated with the radiological assessment could also be improved to increase speed and reliability and to decrease personnel requirements and vulnerability.

Although the current battlefield fallout prediction model could be readily improved (better fallout models already exist), for many different reasons it is virtually impossible to develop an operational prediction capability that will be anywhere near as accurate and reliable as a measurement system. Also, even if such a model could be developed, its required inputs would be virtually unattainable; e.g., one could not ascertain the micrometeorology affecting the transport of the nuclear debris at all times nor the data on enemy weapons and detonation characteristics. Thus, even though the current fallout prediction model could be improved, radiation measurements will remain the only reliable means for assessing fallout radiological hazards. The current measurement procedures, and in particular the current monitoring system capabilities, could be advantageously improved in the areas of data acquisition, communications, and data processing.

Although radiation measurements are the only reliable means for assessing fallout radiological hazards, the task of measuring in detail the radiation over an entire battle area would be prohibitive. An accepted procedure, therefore, is to take spot measurements and to estimate the radiological hazards in the interstitial areas by interpolation. The accuracy of this procedure is directly proportional to the density of the spots measured,

For the purpose of performing comparisons of battlefield radiological hazard assessment systems, these systems were categorized in Section III as measurement systems, semipredictive systems, and predictive systems. Improvement areas for measurement systems (which include both monitoring and survey capabilities) and predictive systems have been indicated in the above discussion. Semipredictive systems, which are still conceptual in nature, combine fallout prediction and fallout measurements to forecast later fallout patterns. Their development depends in large part on improved fallout modeling processes, but they will benefit from any improvements that are made in measurement systems. It appears that a semipredictive system might be developed using fallout modeling technology that is now available. Future developments of fallout prediction models and measurement systems should not overlook the possibility of their future marriage in a semipredictive system. It must be emphasized that estimates of the capability of achieving such a system and of its future potential must be considered speculative until the concept can be developed and evaluated in depth.

In Section V.B it was pointed out that a considerable portion of the division area would be inadequately covered by the current radiation monitoring system. If this system is to be improved, there is an obvious need for a capability of rapidly acquiring radiological dose rate information in battlefield locations not occupied by units equipped with radiological survey meters. This need could be satisfied by using unmanned radiological sensors to complement the manned radiological survey meters. In addition, an improved aerial radiological survey system capable of direct transmission of monitoring data to the CBRE at the division (and possibly brigade) TOC would be very useful in acquiring dose-rate information in areas not covered by manned and unmanned radiological sensors.

The cost and effort entailed in positioning sensors, manned and unmanned, throughout a division area on a 3.2 by 3.2 km grid would be quite large. Thus, there is a need for a capability of emplacing unmanned sensors expeditiously in contaminated areas where manned sensor readings would not be available. Unmanned sensors should be emplaceable by hand, artillery, or airdrop.

The present radiological hazard assessment system, which depends on manual data processing of dose-rate data communicated by voice up the chain of command appears to be adequate, given the present data acquisition capability. Deriving the full benefits of improved radiological data acquisition will probably require better communications and data processing capabilities. The feasibility of an improved battlefield radiological hazard assessment system appears to depend largely on incorporating the capability of supporting this system in other tactical automatic data processing (ADP) and communications systems. In the case of the Army, radiological data transmission and processing functions should be served by the Tactical Operations System (TOS), the Tactical Fire Direction System (TACFIRE), and the Remotely Monitored Battlefield Sensor System (REMBASS). This would assure a rapid gathering and processing of radiological data and its integration with future systems that will support fire and maneuver planning on the nuclear battlefield.

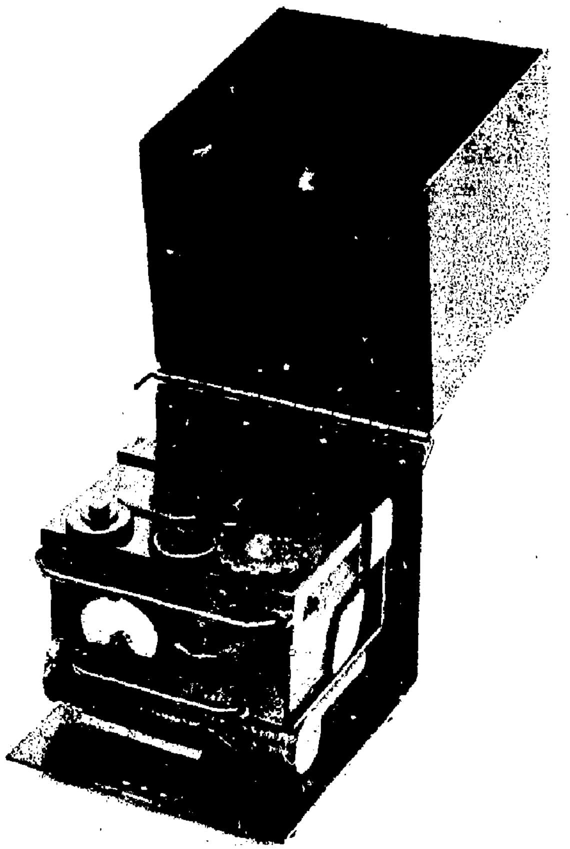
B. Radiological Data Acquisition

1. Manned Sensors

The current battlefield radiological detection and measurement equipment typified by radiacmeter IM-174A may be considered as first generation equipment. It is a hand held piece of equipment used for tactical gamma radiation monitoring and survey. Both vehicular and aerial surveys are now conducted with the IM-174A. The Army is developing second generation equipment to replace the IM-174A in about 1978. The Tactical and Vehicular Radiac Set, AN/VDR-1, will be used for tactical gamma monitoring and survey. The Aerial Radiac System, AN/ADR-6, will provide an airborne gamma survey capability that is not dependent on a hand held radiacmeter in an aircraft.

The Tactical and Vehicular Radiac Set AN/VDR-1, Figure 13, is a wide dynamic range instrument covering monitoring (health physics) ranges of interest as well as tactical levels. The AN/VDR-1 is designed to be used in different configurations for ground use by personnel and in various combat vehicles as an installed system. The range of 1 millirad/hr to 1000 rad/hr is covered in seven linear decades. The detection principle is based on pulsed Geiger-Mueller tube operation. Pulse width and repetition rate are adjusted for each range. The basic set, less installation hardware, weighs about five pounds and is approximately 100 cubic inches in volume. A second generation laboratory development of this instrument using chip technology and light emitting diode (LED) display shows that the manual scale change can be eliminated and a physical volume approaching 3 by 3 by 5 inches appears feasible.[18]

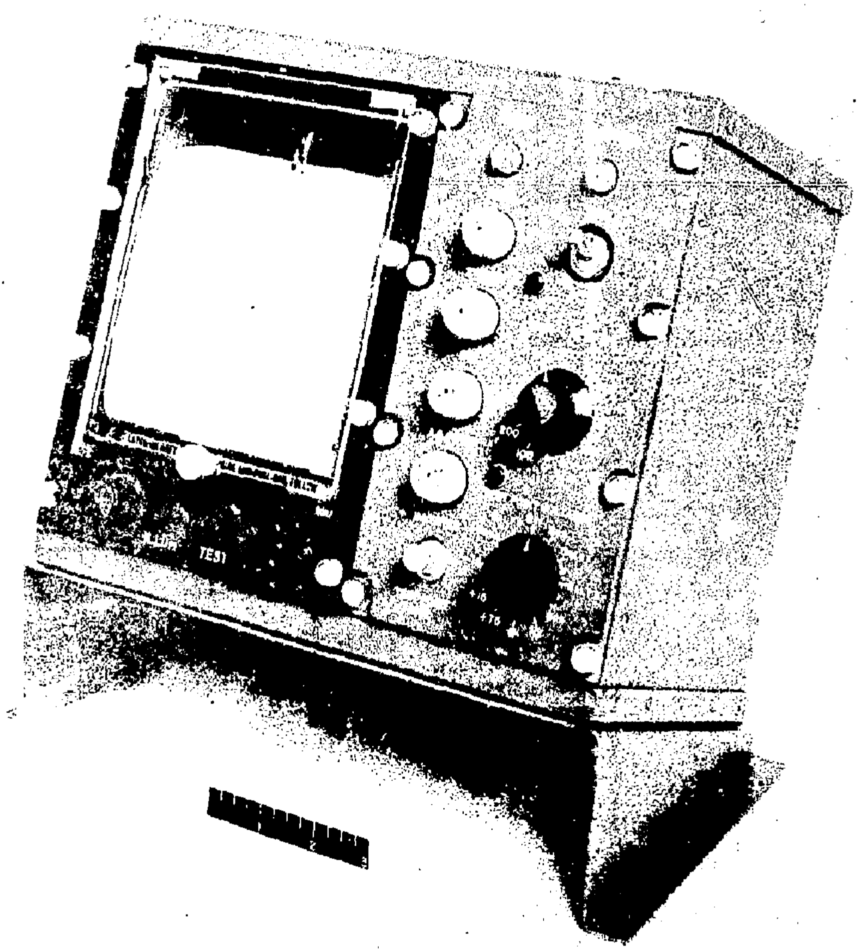
The Aerial Radiac System AN/ADR-6 is shown in Figure 14. This system is intended for use in Army surveillance aircraft, such as the MOHAWK, and utility and observation helicopters. In various configurations it weighs from 30 to 60 pounds and occupies a volume of about one to two cubic feet. The detection principle is based on a high sensitivity photomultiplier-fluor combination. A radar altimeter provides the basis for an air-ground correlation factor. An associated recorder provides the information required.[16] It will use existing navigation,



SOURCE: Reference 16

SA-2605-14

FIGURE 13 RADIAC SET AN/VDR-1



SOURCE: Reference 16

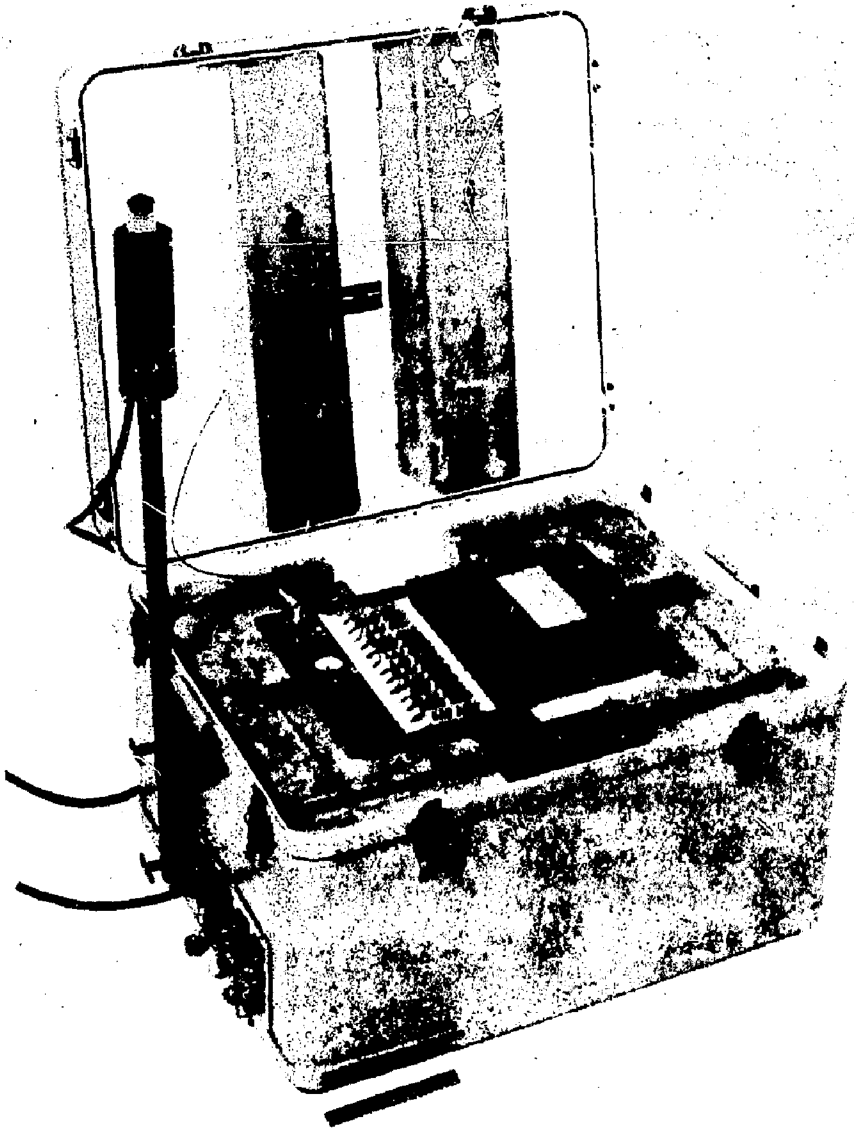
SA-2605-15

FIGURE 14 AERIAL RADIAC SYSTEM AN/ADR-6

position location, and data-transfer capabilities for transmitting height-corrected dose-rate readings and positions to a receiving station on the ground.

The Army also had two third-generation radiac developmental projects, but their present status is unclear because the material need statement for them was deleted on 15 July 1973. The first project was the Miniature Multipurpose Radiac Device (MMRD), visualized as being no larger than 3 by 2 by 1 inches and weighing no more than eight ounces. The MMRD would replace existing standard Army tactical ground survey and monitoring instruments and tactical dosimeters. The second project was the Advanced Aerial Radiac System (AARS), which would be a compact, lightweight, rugged, rapid response system capable of being employed in low- and high-performance manned and unmanned aircraft up to 10,000 feet and at ground speeds up to Mach 3 for the purpose of rapidly and accurately determining the ground radiation dose rate pattern. It appears that the problems associated with the development of the MMRD and the AARS were just beginning to be addressed in early 1973, and no solutions appeared to be available. For the MMRD, several orders of magnitude reduction in size and weight were required without reduction of functional capability of second generation equipment. For the AARS, it would no longer be possible to measure the direct or scattered gamma rays because of the 10,000 foot altitude requirement.

The attainment of an accurate fallout prediction system will depend on the development of tactical nuclear burst sensors capable of determining time of burst, yield, height of burst, and location of ground zero. The Army has been developing a Nuclear Yield Measuring Set, AN/TSS-6, shown in Figure 15. Some problems exist with this development, and it should be noted that it provides only part of the capability needed to support an instrumented radiological fallout prediction system.



SOURCE: Reference 16 SA-2605-16

FIGURE 15 NUCLEAR YIELD MEASURING SET AN/TSS-6
ET/ST Model, Interior View, Showing Panel

2. Unmanned Sensors

One of the most important technological developments of the Vietnam war were the unattended ground sensors (UGS) to provide combat intelligence over wide areas that could not otherwise be kept under continuous surveillance. The UGS are a very essential part of the surveillance, target acquisition, and night observation (STANO) capabilities of U.S. military forces. Sensing techniques used by various types of UGS are seismic, pressure, magnetic, electromagnetic, acoustic, disturbance, and active infrared. In Southeast Asia, the UGS assets were a component of the Battle Area Surveillance System, Phase III (BASS III), which included:

- Phase III sensors, many of which were commandable.
- Phase III portatales* and associated recorders for battalion use.
- Multichannel receiver units and associated display units for brigade and division use.
- FM/FM relay or multichannel universal relay packages (MURPs) for relay subsystems.
- Long-range navigation equipment.
- Command systems.[17]

The BASS III capabilities do not suffice to meet the mobility needs of other conflict areas, and the Army is developing the Remotely Monitored Battlefield Sensor System (REMBASS) for that purpose.

Radiac equipment is included as a class of STANO material. At the present time there is no indication that any radiac UGS exist or are under development; however, the development of UGS for radiological monitoring would be a logical part of the REMBASS program if the need

*A device that receives and displays sensor signals.

therefore is justified. Radiac UGS could be included in other sensor fields that are distributed throughout the division area of operations and in the division's area of interest beyond the FEBA for gathering combat intelligence.

Radiac UGS could be emplaced by hand, artillery, or airdrop in areas not occupied by troop units equipped with hand-held radiacmeters. After a fallout producing nuclear burst, a capability of rapidly emplacing radiac UGS in desired locations would reduce or eliminate the need for sending out ground or aerial radiological survey missions to acquire data necessary for accurate dose-rate contour plotting.

The development of artillery- and mortar-delivered UGS may depend on miniaturization of radiacmeters as envisaged in the Army's MMRD program. The need for radiac UGS may be the best possible justification for pursuing research and development for the maximum possible miniaturization of radiological monitoring equipment.

C. Data Processing

1. Dependence on Other Systems

Data processing of radiological monitoring and survey readings is considered to include all handling of this information from the time the readings are taken until the processed information is displayed for the use of tactical decision makers or is converted into messages warning of expected contamination or locating areas of contamination. Future developments in the area of radiological data processing will include any projected capabilities that could improve on the present voice radio radiological reporting and warning methods and on manual computation and plotting for interpretation of fallout dose-rate measurements. There are no future developments that can be identified as solely devoted to improved radiological data processing: however, the Army's TOS and TACFIRE are scheduled to have an ADP supported capability of assessing nuclear strike effects. In addition, the Army's REMBASS would have the capability of handling data from radiac UGS, if they are developed, as well as from conventional UGS. In the absence of a separate real-time combat intelligence processing system, the REMBASS data would be processed by the TOS ADP capabilities.

Both TOS and TACFIRE will require data communications support. The radiological reporting and warning system at present depends on the composition and transmission of the five NBC formatted messages prescribed for reporting nuclear detonations and radioactive fallout (see Section V.D, page 41). Message entry devices are being developed for both TOS and TACFIRE that are suitable for composing the fixed format NBC messages and transmitting them as digital data messages at speeds much faster than is possible by voice transmission. Such messages would be source data encoded and would be routed directly to the appropriate computer data file for processing.

Radiac UGS data would be reported automatically, periodically, or on command to a REMBASS sensor readout unit, probably at brigade headquarters, where the data would be entered in the TOS system.

TACFIRE will have a fallout prediction program that will include recording of nuclear strikes, processing of meteorological wind data, and fallout prediction based on burst and wind data. The TOS nuclear strike effects program will address the processing of radiological contamination only, based on fallout monitoring and survey reports. This processing will produce a plot of dose-rate contour lines and key dose rates for points, routes, and areas of particular interest. In addition, it will provide for the computation of the maximum time a unit can remain in a contaminated area and the maximum dosage it will receive during that time. Both TOS and TACFIRE will provide a capability of storing and processing current weather and meteorological data, which are a necessary input to their nuclear strike effect programs.

The Army expects to field TACFIRE and REMBASS about 1977 and TOS, with a limited functional capability, about 1980. Implementation of the TOS functional area of nuclear strike effects may be delayed several years beyond 1980. Improved radiac sensor systems and tactical data communications may become available while the Army remains dependent on slow and tedious manual methods of processing radiological measurements. As an interim measure until TOS computational capabilities are available, the development of the microprocessors to replace the cumbersome use of nomograms, curves, and tables in manual radiological data processing should be explored.

2. Tactical Operations System[18,19]

a. System Description

The TOS is designed to receive, process, store, and disseminate information and provide computations and retrieval of information so that command and staff elements are able to make effective decisions. Initially it will operate in support of the division. The system assembles information into files, compiles reports, and maintains a flow of information to those concerned with planning and decisions associated with tactical operations. The users of the system (the staff elements and assigned organizational units at the battalion and higher echelons) have access to the Central Computer Center (CCC) through a Remote Computer Center (RCC). User access is achieved via a system user device, located at the appropriate element of each echelon, that permits input and output of information to enhance operations within a tactical environment.

Each CCC will maintain a data base containing information at a level of detail necessary to satisfy the supported command's functional requirements. A CCC is located at division or higher echelons of command. The major hardware components of a CCC are:

- A general purpose digital computer, consisting of a Central Processing Unit (CPU), a modular memory, an input/output unit, and a control console.
- A Random Access Memory Unit with the capacity and throughput rate to accomplish real time or near real time transactions on the files by the computer.
- A Sequential Access Storage Unit for use as backup storage of programs and data for entry into the computer.

The RCC is a computer facility located at brigade and higher echelons that facilitates and provides for an orderly interface between system user devices and the CCCs. As part of this interface function, the RCC performs preliminary processing (error checking and access control) of messages being input to the CCC, and output formatting and security checking for messages being output from the CCC to remote devices. The RCC also supports the local control and user devices at all echelons. It does not duplicate the centralized data base of the CCC.

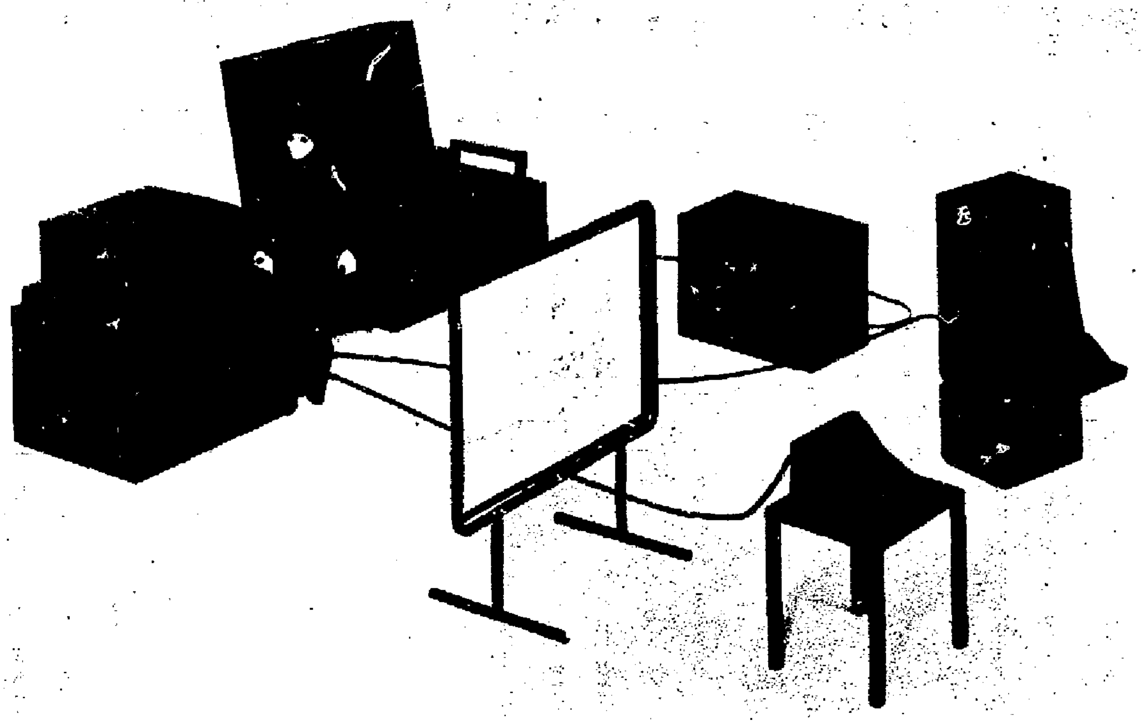
Three system control devices permit flexibility of TOS employment and configuration. The Tactical Control Console (TCC) monitors and controls the status of CCC users. The Computer Center Control Console (C_4) monitors and controls the computer center status. The Communications Network Control Station (CNCS) is used to monitor and control TOS communication networks and the communication interfaces with the computer centers.

There are four TOS system user devices: the Group Display Device (GDD), the Analysis Console (AC), the Message Input/Output Device (MIOD), and the Message Input Device (MID). Data inputs can be entered below battalion level through the MID. Access to the system by its principal users is provided by the MIOD, the AC, or the GDD. These devices communicate with the RCC, which provides for access to the data maintained in the CCC.

The GDD will be capable of portraying friendly and enemy unit locations, boundaries, front line traces, zones, and area contours on a tactical map background. The device will have the capability of displaying alphanumeric, symbolic, and graphic information from a digital data source onto standard U.S. Army map representations or their projections. It will also provide a hard copy (transparent) reproduction via the overlay producer.

As noted previously, the TOS nuclear strike effects program will produce a plot of radiological fallout dose-rate contour lines. It is anticipated that these will be displayed on the GDD superimposed on the projection of a standard Army map of appropriate scale. The plotted contour lines will then be printed as a monochromic transparent overlay keyed to that map. Overlays suitable for use with standard Army maps (approximately 18 by 18 inches) could be transmitted in 2.5 minutes or less by a digital facsimile system using data compression and high speed modem technology.

The ultimate objective for the TOS GDD is for a large, real time, multicolor, computer driven panel display that is compatible with military maps and the military environment. An advanced development equipment now provides a monochromic display using projection optics, with reusable photochromic film serving as the image writing plane. The scale model in Figure 16 shows the Photochromic Film Display, the Overlay Reproducer, a Control Keyboard, and a Display Entry and Editor Monitor. The Photochromic Film Display will be converted to a polychromic



SOURCE: Reference 20

SA-2605-23

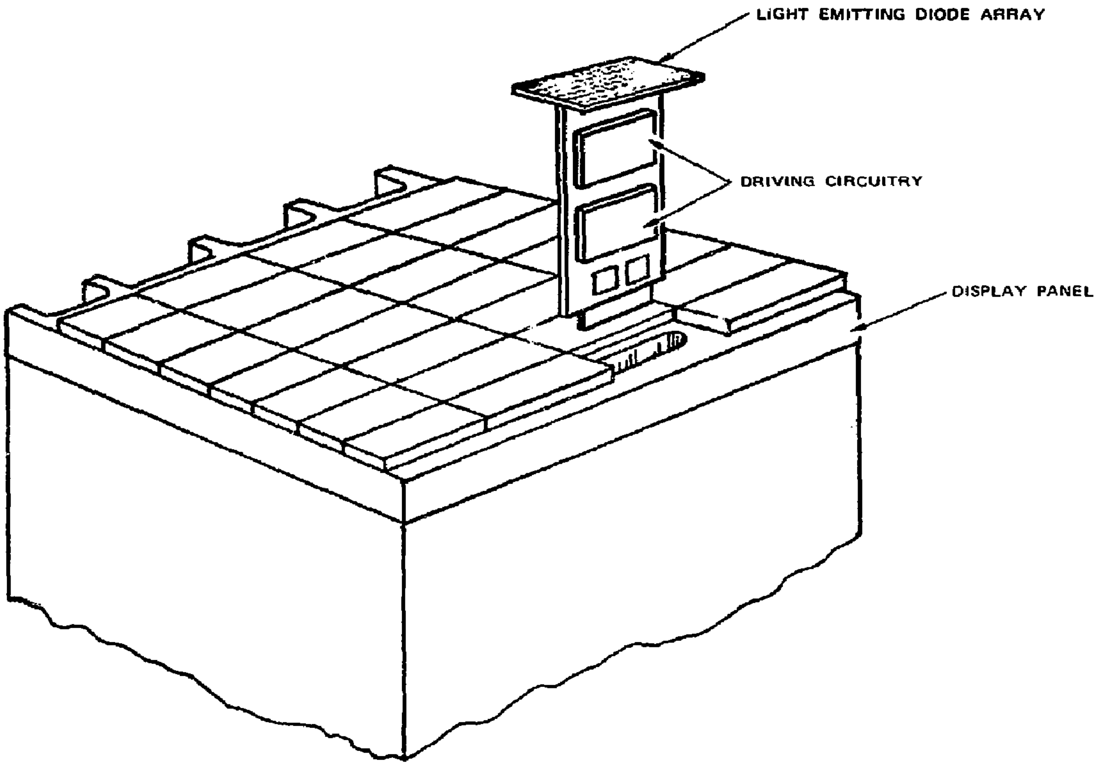
FIGURE 16 MONOCHROMATIC DISPLAY SCALE MODELS presentation as technology is developed on the multicolor use of photochromic film. The desired characteristics of this display are:

- Large screen display--4.5 by 6 feet.
- Reusable dry film process.
- Dynamic overlay data superimposed on a projected military map.
- Selective write/erase (probably using laser) while viewing data.
- Multicolor capability.

The U S. Army Electronics Command also has two other developmental programs for TOS display devices--a monolithic light emitting diode (LED) display and a liquid crystal display, both directed to alphanumeric and vectographic presentations. Large size LED displays will be assembled in a mosaic fashion, using mass producible modules measuring 1.5 by 0.75 inches, each containing 512 LEDs. Figure 17 shows a multicolor LED display now undergoing test and evaluation. Resolution will be on the order of 70 to 100 lines per inch, or comparable to facsimile imagery. Large size liquid crystal displays may be more difficult to achieve, but if used in the reflective mode they would be very useful in environments with high ambient lighting.[20]

The AC will provide the man/machine interface between the staff analysts and the computer. It will display Army maps in reduced scale combined with electronically generated characters, symbols, lines, vectors, contours, and so forth. It operates both as a graphical display and an input/output device allowing the user access to the computer data base.

The MIOD within the TOS structure provides the system user with a means for communicating with the system and the capabilities of visual display and hard copy generation. The MIOD will display message formats, provide for notification to the operator of composition errors



SOURCE: Reference 20

SA-2605-24

FIGURE 17 ADP ORIENTED MODULAR PANEL DISPLAY detected in the message, and allow for visual inspection of the complete message before transmission to the RCC.

The MID is an input device, located at company level and at other information sources. Messages entered into the system by a MID are routed to the battalion MIOD. Here they may be reviewed manually and forwarded to the brigade RCC, reviewed but not forwarded to the brigade RCC, forwarded to the brigade RCC without review, and/or printed out on hard copy.

The configuration of a field army TOS and the generalized types of communications links between the various TOS echelons are shown in Figure 18. The proposed equipment distribution is shown in Table 2. The initial software capability will be limited to friendly situation, enemy situation, and Army aviation operations. However, plans for follow-on software development call for the Nuclear Strike Effects function, which among other things would generate fallout dose-rate contours.

b. Communications for the TOS

At echelons from the brigade level upward where Army Area Communications System (AACOMS) capabilities are available, the CCC-CCC and CCC-RCC interconnections will be provided by dedicated, full-duplex, multichannel data and engineering circuits; at echelons below brigade level the TOS users will be interconnected primarily by FM radios. The battalions of a brigade may be serviced for both input and output by a single channel (half-duplex) radio net. Users at echelons below battalion level will use organic FM radios as the primary means of interconnection with the TOS.

FM radio (or wire) data circuits will be required for each MIOD-RCC link (other than local links). Battalion MIODs linking with a

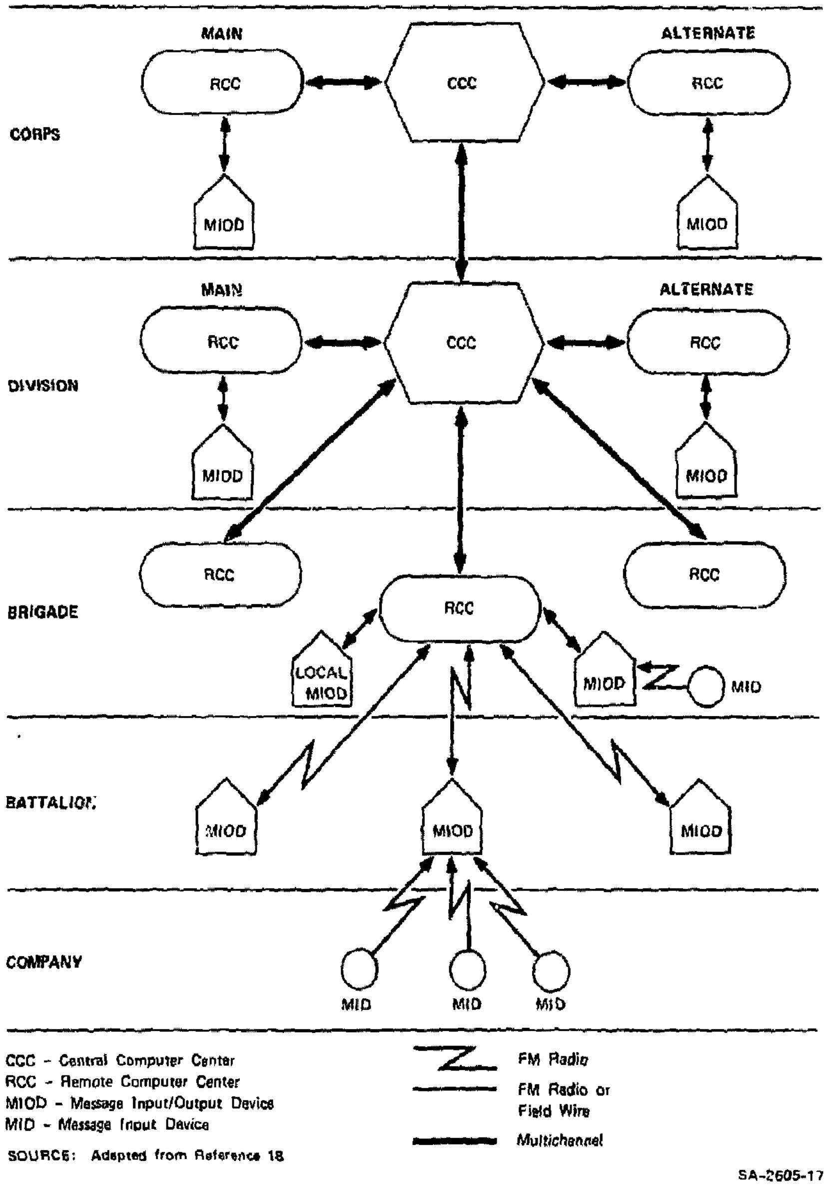


FIGURE 18 TACTICAL OPERATIONS SYSTEMS COMPONENTS AND COMMUNICATIONS

Table 2

TOS EQUIPMENT DISTRIBUTION

Equipment	Echelon			
	Division	Brigade	Battalion	Company
Central computer center	1			
Remote computer center	2	1		
Group display device	1	1		
Analysis console	>1	>1	1	
Message input/output device	>1	>1	1	
Message input device	>1	>1		1

brigade RCC will share the organic FM link. This net will operate in a half-duplex mode, and only one MIOD or the RCC can transmit at any instant.

FM radio (or wire) data circuits will be required for each MID-MIOD link. Communications will be provided by organic FM nets between battalions and subordinate companies operating in the half-duplex mode.

Except for the transmission media, all other aspects of TOS communications will be organic to the TOS elements. Control of information flow, as well as information (message) acknowledgement and accounting will be performed within the software capabilities of the TOS equipment. Error detection and correction of data passed between TOS elements will also be performed by TOS equipment.

The TOS will require system interface devices (data terminals) to interface the TOS hardware components with the principal communication equipments and networks (tactical radio nets, wire nets, cables, AACOMS, and tactical satellite communications). From the standpoint of tactical radios, the major functions of the TOS system interface devices are to provide:

- Interface and transmitter keying capability for half-duplex tactical AM/FM radio equipments.
- Conversion of data signals from digital to analog and from analog to digital.
- Capability for "secure" operation using communications security (COMSEC) equipment.
- Capability for "clear" operation when COMSEC equipment is not used.
- Capability for error detection and correction.
- Capability of passing data from communication equipments and networks and from computer hardware components.

For efficient TOS data flow on a tactical radio net, the data transmissions will be strictly controlled. A communications control subsystem will inform a station in a net when it may transmit. Should data transmission occur without being directed, the transmission will be ignored by the communications control subsystem. This subsystem will establish the sequence in which stations in the net (including the control station) will transmit data.

3. The Tactical Fire Direction System[21]

a. Operational Employment

The purpose of TACFIRE is to increase the effectiveness of field artillery firepower by applying automatic data processing to selected functions of field artillery operations. TACFIRE will comprise a completely integrated system of computer complexes that will be located at specific artillery echelons from battalion through corps artillery. Communications will be provided by contemporary standard wire and radio channels. Digital messages will be transmitted at 600 and 1200 bps.

TACFIRE will be capable of processing and transmitting classified data up to and including Top Secret Restricted Data.

At the lowest operating echelon the system operates as follows (assuming a fire mission is being transmitted):

(1) The artillery forward observer (FO) sends his fire mission in digital form from his Fixed Message Entry Device (FFMED) directly to the battalion fire direction center computer.

(2) The computer--using its major program and its applications and operating system programs--analyzes the target, computes the ballistic solution, determines the fire commands, and presents them to the S3 for acceptance, modification, or negation.

(3) After approval or modification by the S3, the commands are transmitted in digital form directly to the display unit(s) at the firing battery (batteries) for action.

(4) These actions are accomplished primarily by two of the six major application programs found at the artillery battalion level--the two programs being the Tactical and Technical Fire Control Programs. The other four programs are nonnuclear fire planning, ammunition and fire unit status, artillery survey, and meteorological data.

As mentioned before, TACFIRE will have a fallout prediction program. It will compute prestrike fallout prediction, maintain files of nuclear burst sightings, and provide troop safety warnings in the event of nuclear strikes. The computer software for this program will support the Fire Support Element (FSE) at the Division TOC. Artillery elements that have a capability of measuring nuclear burst parameters will make NBC 1 reports using their FFMEDs. These reports are input in real time to the TACFIRE AN/GYK-12 computer, and the FSE fallout prediction program will generate real time outputs to operators for use and dissemination.

This TACFIRE computer output could be printed out on the Electronic Line Printer and displayed on the Electronic Tactical Display (and possibly on the Digital Plotter Map).

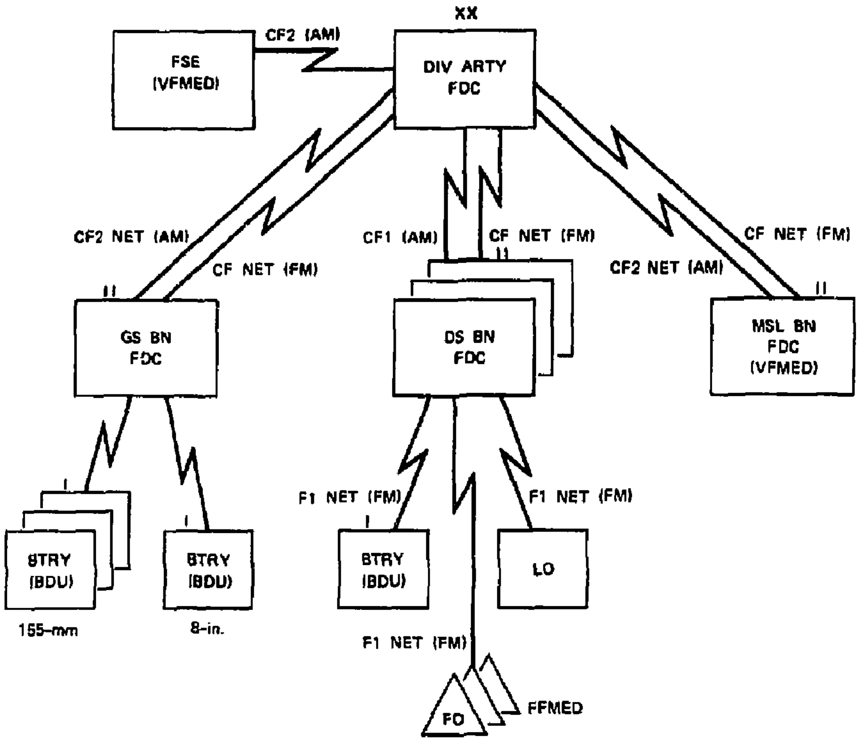
A capability for immediate reversion to degraded and manual operation is provided to permit continuation of effective operations in the event of malfunction or destruction of key elements of TACFIRE.

b. Communications

TACFIRE communications consist primarily of VHF-FM radio nets, field wire, and HF-SSB radio sets. However, TACFIRE has the capability of operating half- or full-duplex at speeds up to 1200 bps over all field army tactical communication systems. Artillery communication doctrine and organization are unchanged by the introduction of TACFIRE, in that the same radio and wire communications will be used for digital traffic. As a result, digital and voice traffic share the same communications systems. All communications use the ASCII code for character representation, including communications control symbols. Typical artillery radio nets for TACFIRE are shown in Figure 19.

Messages are two basic types: variable length, variable format; and fixed length, fixed format. The fixed format messages are associated with message entry devices used by the FO. The variable format messages, which usually originate within the fire direction centers (FDCs), are associated with the artillery consoles and keyboard entry devices. A variable format message consists of two parts: a designator and an argument, which are both fixed in format. However, the size of the argument can vary within specified limits.

The components used as transmission devices are the FFMED, the Variable Format Message Device (VFMED), the Battery Display Unit (BDU),



DIV ARTY - Division Artillery
FSE - Fire Support Element
GS BN - General Support Battalion
DS BN - Direct Support Battalion
MSL BN - Missile Battalion
BTRY - Battery
FDC - Fire Direction Center

LO - Liaison Officer
FO - Forward Observer
CF - Command and Fire Direction
F - Fire Direction
BDU - Battery Display Unit
VFMED - Variable Format Message Entry Device
FFMED - Fixed Format Message Entry Device

NOTE: Two other nets, F2 and F3, are identical for each BN.
SOURCE: Reference 21.

SA-2605-18

FIGURE 19 TYPICAL TACFIRE RADIO NETS

the Data Terminal Assembly (DTA), and the Monitor Patching and Control Unit (MPCU). These are described briefly below:

FFMED--The FFMED is a one-way transmission device (transmit only) except for receipt of an acknowledgment from the FDC. It is normally used by the FO and operates on nonsecure links. The FFMED will permit setting up a complete message, visual verification that the correct message type and data have been selected, and actuation of transmission of the completed message by wire or radio. The capability will provide for:

- Transmission of 16 types of fixed format messages consisting of 30 characters each.
- Transmit rate of 600 or 1200 bps.
- Receive and display (visual and audible) acknowledgment from receiving terminals.
- Interface with all types of radio or wire equipment currently in use by the artillery.

VFMED--The VFMED is a remote terminal that is capable of both generating and receiving messages not suited to fixed format, of providing automatic acknowledgment of received messages, and of requesting retransmission of the last message received on initiation of switch action. VFMED messages up to 500 data characters in length can be accommodated in one transmission. Hard copy of messages sent and received will be provided.

BDU--The BDU is a remote terminal located at the firing battery. It is a receive-only device providing the capability to receive and generate a hard copy of variable-format variable-length digital data messages. The unit provides an automatic and manual acknowledgment facility and is compatible with the security equipment TSEC/KG-31.

DTA--The DTA is a part of the computerized FDC, the VFMED, and the BDU. It performs the following functions:

- Accepting information in the form and format of the data source and converting the information into the proper format for transmission.
- Performing error detection and correction.
- Generating synchronization and control characters.
- Receiving signals from the communications media and changing format to a form acceptable to the data processing segment.
- Interfacing key generators TSEC/KG-30 and TSEC/KG-31 for on-line encryption-decryption.
- Providing two- or four-wire, half- or full-duplex digital transmission.

MPCU--A DTA will accommodate either a radio or wire net, but not both simultaneously. The TACFIRE MPCU will provide the flexibility of allowing net subscribers to operate with the most available transmission medium; e.g., radio, wire, or radio relay. It will provide a cheaper, more flexible solution to the radio wire integration requirement for TACFIRE than the Data Transmission Unit (DTU), which consists of an assembly of four DTAs. The current DTU, which the MPCU would replace, will operate at an output rate of either 600 or 1200 bps (switch selective). It will accept digital data in parallel form from the user device and will deliver the data in serial analog form to communication links, using frequency shift keying (FSK) modulating frequencies of 1200 Hz and 2400 Hz. The DTU provides a 12-bit Hamming coded character, comprised of a 7-bit ASCII character, an odd parity bit, and an additional four check bits. This will permit a single-bit error in a character to be corrected and will detect the occurrence of two error bits in a character. In addition, the DTU performs character interleaving to protect against burst errors.

The TACFIRE System has the capability of providing secure digital transmission (up to and including Top Secret Restricted Data) between computers and to or from each remote terminal, with the exception of the FFMED. The FFMED was not included as a secure transmission link because of nonavailability of compact, portable crypto devices and perishability of information from the FO. The FFMED transmission link (FO to the battalion FDC) will be secured when COMSEC equipment becomes available. Although the capability is provided, it is not intended to furnish TACFIRE the key lists for transmission of data classified higher than Secret Restricted. All classified messages must be encrypted by the key generator before transmission. When an encrypted message is received, it must be decrypted before it is processed. If a key generator (KG) is attached to a VFMED or a BDU, all transmission to the device, including acknowledgments, must be encrypted before transmission, because the KG is attached directly and cannot be bypassed.

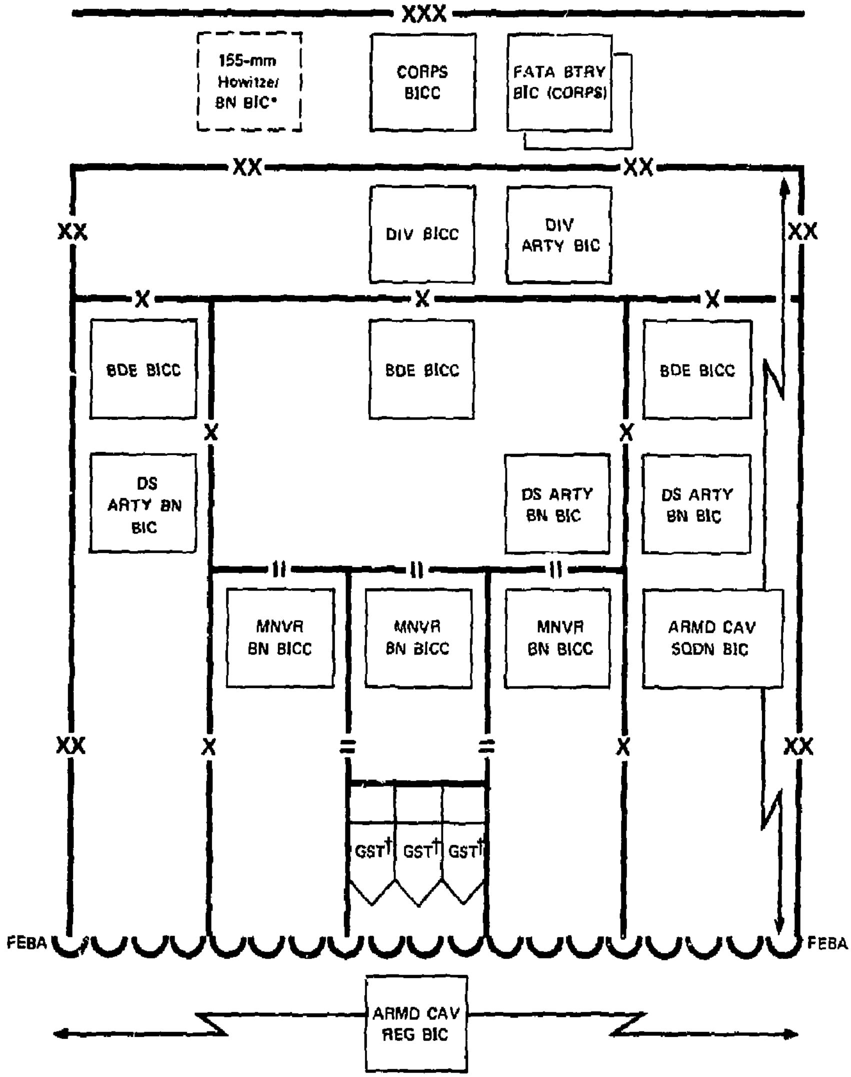
To interface TACFIRE with any other system, it is first necessary to identify the specific messages to be exchanged and design (if necessary) the software modules and hardware to handle those messages. The existing TACFIRE software design is amenable to this type of change. Second, it is necessary to specify the codes, speeds, and other technical characteristics of the communication links that will be used in the interface. Since TACFIRE employs a general purpose digital computer at the FDCs, this computer can be programmed to perform code translations and speed changes. These translations, however, require processor time and should be avoided if possible. Further, these code translations cannot be accomplished by remote units that do not have a computer.

TACFIRE will be electrically compatible with the TOS, since identical equipments are used. This interface will provide for exchange of intelligence and target information.

4. Remotely Monitored Battlefield Sensor System

REMBASS is being developed by the Army to exploit the capabilities of unattended ground sensors, to fill the gaps in coverage provided by existing combat surveillance and target acquisition means, and to provide early warning of enemy activity. The system will be able to assume many different configurations in offensive and defensive operations in different environments in any part of the world, serving all echelons from small unit patrol to division. REMBASS will interface with TOS and TACFIRE and will provide combat intelligence inputs to the Battlefield Information Control Center/Battlefield Information Center (BICC/BIC).[16]

The REMBASS will replace the Battle Area Surveillance System, Phase III (BASS III), which was developed for use in Southeast Asia and is neither adequate nor adaptable for all levels of conflict on a worldwide basis without extensive modification. It is envisioned that the information collected by the REMBASS will be processed at and disseminated from the BICC/BIC of the Tactical Operations Centers (TOCs) at and above maneuver and artillery battalion echelons. The basic components of the BICC/BIC system are shown in Figure 20. The ground surveillance teams shown in the maneuver battalion area operate both the manned and unmanned ground sensors. The personnel to staff the BICC/BIC and to operate both manned and unmanned battlefield sensors are expected to be assigned to the combat intelligence (CBTI) organization. The BICC/BIC will be the major element of the intelligence subsystem of the future Army Integrated Battlefield Control System (IBCS) at battalion, brigade, armored cavalry squadron, division artillery, and division echelons, and also at echelons above division. A requirement for ADP support of the BICC/BIC system has not yet been developed, but in the era beyond 1985 it should be supported by a real-time information and processing system, with computer-to-computer data links. Although automatic interface between the REMBASS and tactical



* When authorized for direct support of armored cavalry regiment.
† Ground surveillance teams.
SOURCE: Reference 22.

SA-2605-19

FIGURE 20 BASIC COMPONENTS OF THE BICC/BIC SYSTEM

ADP systems such as TOS is desirable, initial interface could be provided through the use of a message entry device compatible with each system.

The REMBASS consists of the following five elements:

- The sensors perform the function of detection and, in some cases, the function of target classification.
- The sensor control module (SCM) monitors a sensor field, stores sensor reports, and transmits the reports as commanded.
- The radio relay (RR), both single channel and multichannel, extends the range and overcomes line-of-sight restrictions.
- The universal control receiver/transmitter (UCR/T) is the communications terminal for receipt of sensor reports and for transmission of commands for sensor control.
- The sensor reporting unit (SRU) augments the UCR/T by displaying and recording sensor reports.

Figure 21 depicts some of the configurations for REMBASS. The unattended ground sensors can be emplaced by hand, by air drop, or ballistically. They represent many sensing and detecting technologies--seismic, acoustic, magnetic, electromagnetic. The sensors may transmit directly to the universal control receiver/transmitter by radio or hard wire, or they may report through a RR and/or a SCM.

The UCR/T and the SRU will provide for the display of the data transmitted from the sensor. The display techniques include visual, aural, and permanent record charts, as appropriate to the employment of the system and the specific requirements of the user.

Separately identified, and independent from the balance of a REMBASS system, is the Small Unit Package (SUP). The SUP consists of small inexpensive sensors reporting to a self-contained receiver and display; it is designed for use by platoon and outpost size units.

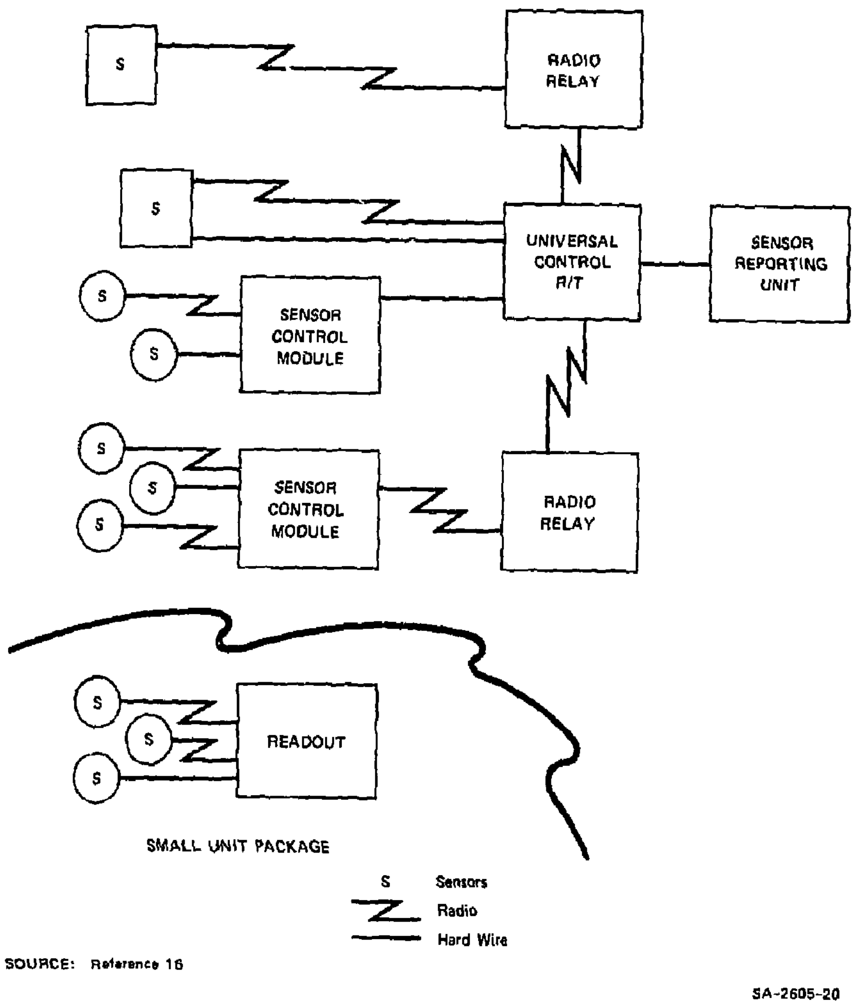


FIGURE 21 REMBASS SYSTEM—CONFIGURATIONS

Although the REMBASS will use a wide variety of unattended ground sensors (seismic, acoustic, magnetic, and so on), capable of being emplaced by hand, ballistically, or by air drop, no specific requirement has been stated for similar types of sensors for detection of radiation on the battlefield. Since the REMBASS threat environment (for example in Europe) includes nuclear operations, the development of UGS with a radiac capability and their inclusion in the REMBASS would be very logical. The radiac UGS would augment rather than replace the manned radiac equipment.

On the battlefield of the future against a technologically sophisticated enemy under the threat of tactical nuclear weapons, our force deployments will be characterized by wide unit dispersion. Unattended ground sensor fields will be used extensively forward of the positions of our forces to detect enemy activity, and will be used in the gaps between our dispersed units to detect enemy penetrations. The radiac UGS should be deployed with other types, if the use of tactical nuclear weapons is anticipated. Additional radiac UGS can be emplaced by ballistic delivery means (mortar or howitzer) in locations where additional fallout radiation rate information is needed for the plotting of radiological contour map overlays. An artillery delivered sensor could be emplaced accurately by a 155-mm howitzer out to a range of about 15,000 m. A mortar delivered sensor (MODS) similar to the AN/GSQ-136 seismic MODS[17] could be delivered by an 81-mm mortar out to a maximum range of about 3,300 m. Various techniques are available to reduce the impact of a ballistically delivered sensor; e.g., containers in base ejection shells, with or without parachutes.

The placement of radiac UGS would be planned and directed at the brigade level, as is the case for other types of UGS. The monitoring of radiac UGS readouts should also concentrate at the brigade BICC and be disseminated to higher echelons and adjacent brigade BICCs. Radiac sensors associated with rear area sensor systems for headquarters, logistic element, and large installation security would extend the fallout assessment capability throughout the field Army area, with readout at the command posts responsible for rear area security.

The reporting of radiological dose rates recorded by manned radiac equipment should probably be reported via the TOS by message entry device. In the case of unmanned radiac sensors, the logical reporting chain parallels that for other UGS--through the BICC/BIC that is a part of the TOC at battalion and higher echelons. It is probable that the REMBASS radio communication frequencies will be higher than the normal range of the VHF-FM tactical net radios, which is now 30 to 76 MHz, so readout of radiac UGS at company level would require additional radio equipment and compound the frequency allocation problem.

A radiac UGS will require sufficient communications range to reach the closest point of entry into the REMBASS communication system--a SCM, a RR, or a UCR/T. If deployed with other sensors in a sensor field, it probably should be located close to a SCM and hard-wired to it. Otherwise, the radiac UGS radio should have a line-of-sight (LOS) communications range of at least ten km, and RRs should be positioned accordingly. Extended LOS ranges could be obtained by airborne sensor readout or relay facilities. Airborne readout of radiac UGS could frequently substitute for an aerial radiac survey system.

If the requirement for radiac unattended ground sensors as part of the REMBASS is recognized and approved in the relatively near future, there appears to be no problem in incorporating a capability for radiac sensor data transmission and readouts in the SCM, RR, UCR/T, and SRU elements of the REMBASS. The radiac UGS should have the following characteristics:

- Deliverable by hand, mortar, howitzer, or air drop.
- Equipped with receiver as well as transmitter to provide commandable capability.
- Transmission range at least comparable to other UGS.
- Probe height one meter above ground when emplaced.
- Internal tilt meter, generating data field indicating tilt from vertical in ten degree increments. (The dose rate readings of a tilted sensor need correcting to a value at one meter above the ground.)
- Dose rate indicator, generating a dose rate data field showing rates from 0 to 1000 rad per hour in graduated steps.
- Transmitter turns on and sends alarm signal intermittently when dose rate reaches five rad per hour.
- After initial interrogation following transmission of alarm signal, sensor transmits dose rate readings only on command.
- Capable of having settings made externally before final emplacement that will include in the data message:
  - A discrete identification code (which may be sufficient to establish location)
  - A position location in a grid coordinate system (desirable).
- Other characteristics as prescribed for comparable REMBASS sensors.

D. Concept of a Future Radiological Hazard Assessment System

The foregoing discussion of planned and possible improvements in radiological data acquisition and data processing capabilities has indicated the basic elements of a future improved radiological hazard assessment system. These elements are:

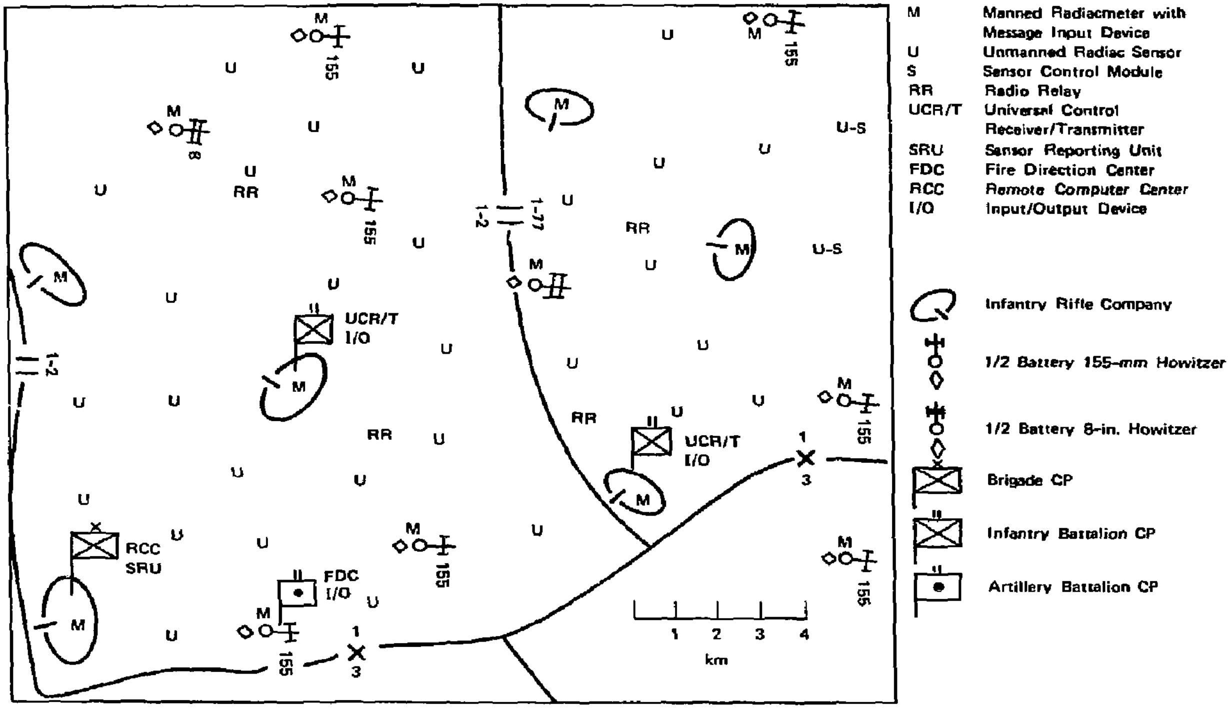
- Improved hand-held radiological monitoring and survey radiacmeters.

- An aerial radiac survey system not dependent on hand-held radiacmeters and adaptable to either manned or unmanned aerial vehicles.
- Data processing of nuclear strike effects data by TOS and TACFIRE, and possibly by microprocessors. Rapid display of processed data for timely, judicious decisions.
- Unmanned radiac sensors for measuring gamma radiation, incorporated in the REMBASS.
- Data transmission of radiological measurements using TOS, TACFIRE, and REMBASS communications capabilities.

Figure 22 illustrates the deployment of units for tactical nuclear warfare in approximately one-half of a brigade area, about 330 square kilometers. The deployment of manned and unmanned radiac sensors and of pertinent elements of TOS, TACFIRE, and REMBASS is also shown. The manner in which these elements can be interconnected and integrated into an improved radiological hazard assessment system for an Army division is shown in Figure 23.

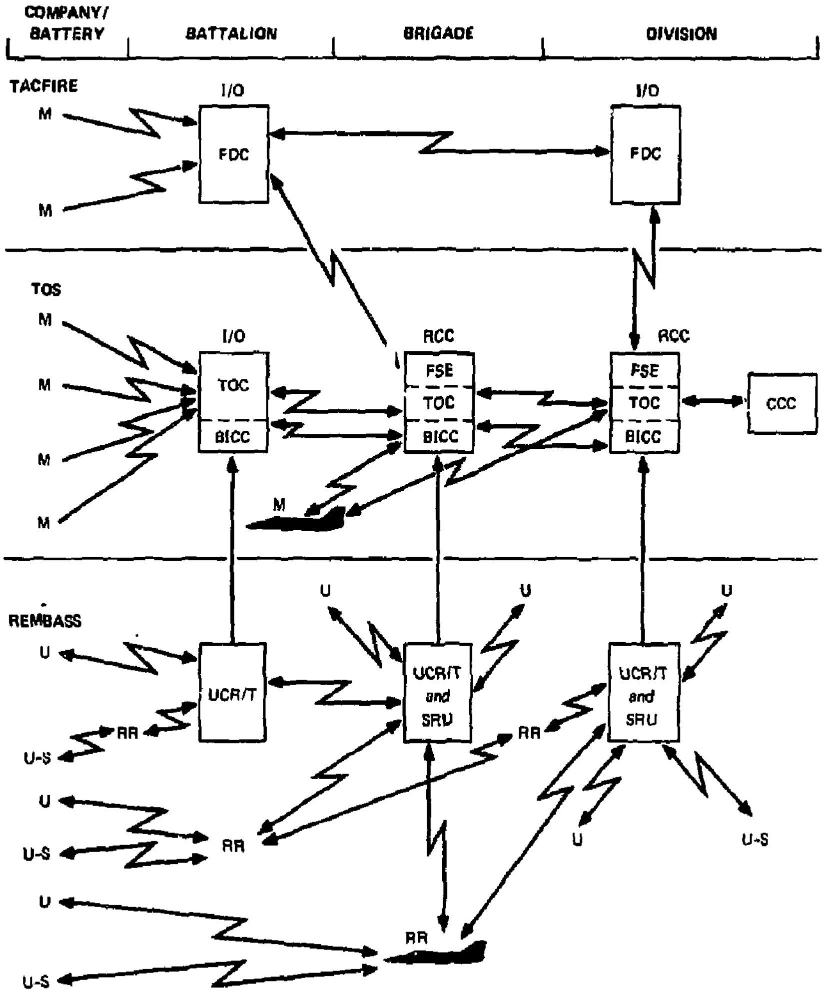
The future radiological assessment system would have the following advantages over the current system.

- It is not wholly dependent on manned instrumentation for dose-rate measurements or on manned radios for transmission of measurement data to NBC analysis centers.
- It can obtain dose-rate measurements in contaminated areas that are not immediately accessible to man:
  - Areas that are too "hot" radiologically, and where men and instrument sources of measurement data are inoperative.
  - Friendly areas not occupied by troop units with a measurement capability.
  - Enemy held areas in which friendly operations are planned.
  - Areas that have been overrun or evacuated during withdrawal operations in the face of enemy offensive or breakthrough operations.



SA-2605-21

FIGURE 22 DEPLOYMENT OF UNITS AND ELEMENTS OF AN IMPROVED RADIOLOGICAL HAZARD ASSESSMENT SYSTEM



M - Manned Radiacmeter with Message Input Device
U - Unmanned Radiac Sensor
S - Sensor Control Module
RR - Radio Relay
UCR/T - Universal Control Receiver/ Transmitter
I/O - Input/Output Device

TOC - Tactical Operations Center
BICC - Battlefield Information Control Center
SRU - Sensor Reporting Unit
FDC - Fire Direction Center
FSE - Fire Support Element
RCC - Remote Computer Center
CCC - Central Computer Center

SA-2605-22

FIGURE 23 IMPROVED RADIOLOGICAL HAZARD ASSESSMENT SYSTEM

- It has a higher probability of surviving as a viable system if elements in the hierarchical chain-of-command reporting system are rendered inoperative. Operational degradation of the system would more likely be relatively graceful rather than catastrophic.
- The processing of dose-rate measurement data and presentation of analysis results for decision making at each echelon of command requires much less time and effort. This data processing product will be more dependable because the input data will have fewer gaps.
- Both the communication system and the data processing system are less susceptible to saturation caused by multiple fallout-producing bursts.

The primary advantages of the improved system over the current system lie in the areas of (1) timeliness of data acquisition and processing and (2) greater reliability and completeness of processed data used for decision making and operational reaction.

An estimate of the time required for each consecutive action between the monitoring by company personnel and the execution of orders issued from the division level is shown in Table 3.

It can be seen that the improved system is estimated to be capable of reducing the time required for data acquisition and processing from about 40 minutes to about 6 minutes. For a single fallout-producing nuclear burst over a period of several hours, a time lag of 40 minutes may be acceptable. If multiple fallout-producing bursts occur over a period of several hours, the utility of the current system becomes doubtful, whereas the faster data acquisition and processing time of the improved system would have an excellent chance of supporting radiation hazard assessment adequate for continued decision making.

It will be noted that the reaction times for operations based on the display of the processed radiation dose-rate measurements remain essentially the same for both the current and improved systems. The advantage

Table 3

TIME REQUIRED FOR ACTIVITIES BETWEEN FALLOUT MONITORING AND OPERATIONAL REACTION TO RADIATION HAZARDS

Activity	Current System Capability (minutes)	Improved System Capability (minutes)
Data acquisition and processing		
At Company level	5	1
At Battalion level	5	1
At Brigade level	10	1
At Division level	20	3
Reaction		
Decision at Division	5*	5*
Issue of orders, Division	3	3
Issue of orders, Brigade	2	2
Issue of orders, Battalion	2	2
Execution preparation time	15	15

*If the decision entails a counterattack, this time would be about 30 minutes.

that accrues to the improved system is that the greater accuracy and completeness of its processed data has a high probability of resulting in much better decisions.

VII CONCLUSIONS AND RECOMMENDATIONS

The current radiological hazard assessment capabilities reside in three systems: prediction, monitoring, and surveys. Common to the three systems are a communications capability and a data processing capability. The prediction capability is very unreliable and its usefulness is limited to preliminary operations planning. The monitoring coverage is marginal, and where it is inadequate survey operations are used to fill the data gaps. The current monitoring and survey capabilities, however, require a significant amount of time to delineate the battlefield radiological environment. Therefore, in situations where the battle tempo is relatively fast, the speed with which current capabilities could produce assessment results is inadequate.

The reasons that the current assessment capabilities are slow are many. Each of the following component functions require a significant amount of time, and these delays are cumulative:

- Voice reporting of radiological monitoring up through the chain of command.
- Recording and processing of reported data by manual procedures.
- Recognition that surveys are necessary to supply missing data.
- Planning and conduct of surveys.
- Nonavailability of complete survey data until survey mission reaches last survey point or survey vehicles return to base.

Hence, it is doubtful that the present radiation hazard assessment system could provide the timely results necessary for the command and control of tactical nuclear operations.

Battlefield radiological hazard assessments could be speeded by increasing monitoring capabilities to the point where radiological surveys are not required. The time required for data acquisition and processing could also be significantly decreased. The recommended battlefield radiological hazard assessment system is a highly automated integrated system for handling all the activities of radiological assessment from radiation sensing to the displaying of processed data. The system's sensors would include a new family of unattended sensors emplaced by hand or remotely by artillery or aircraft, in addition to improved manual sensors. The sensors' measurements of radiation would be coded signals, transmitted by radio to programmed centrally located receivers and data processing computers. The processed output would be in graphic as well as tabular form. The elapsed time from data acquisition to processed data output need only be a few seconds. The recommended system is within the current state of technology, and some of the components for such a system already have been developed, or are now being developed.

The recommended system would evolve from the present system, primarily by taking full advantage of other system developments now being pursued by the Army* on a high priority basis. The one system element that is not now being developed, and on which the full realizable capability of the system depends, is the unmanned radiac sensor which has been described herein. The highest priority should be accorded to the development of unmanned radiac sensors and their incorporation into the REMBASS system capabilities. This could be accomplished by the time the REMBASS becomes operational about 1977 or 1978.

---

*Other military departments are pursuing similar developmental programs in the command control and communications area. Examples in the case of the U.S. Marine Corps are the Marine Tactical Command and Control System (MTACCS), the Marine Search and Attack System (MARSAS), and the Landing Force Integrated Communications System (LFICS).

In the normal course of development of TOS and TACFIRE, an improved capability of assessing nuclear strike effects by ADP will be achieved. This evolutionary process should be speeded up by according higher priority to the development of the proposed TOS nuclear strike effects functional area. Since the TOS capabilities will not be available in the field until after 1980, interim ways of providing computer assistance to the present complicated and tedious methods of radiation hazard assessment calculations should be sought. The possibility exists of using the TACFIRE computer or of developing specialized preprogrammed microprocessors (which could eventually be used as the fallback mode of operation if TOS capabilities are lost).

The foremost justification for the improved radiological hazard assessment system and for according it a high priority for development and funding is simple and compelling--without it our land combat forces might be deprived of the capability of effective maneuver on the nuclear battlefield. They will either be immobilized in shelters that are available to them or will suffer excessive and unnecessary casualties due to radiation exposure.

The same justification applies to improved educational and training programs for increasing the readiness of ground tactical combat forces for operations in a nuclear environment. This would ensure that, whatever the state of evolution of the system might be, the maximum tactical benefits could be derived from it.

REFERENCES

1. "Tactical Nuclear Operations," Field Manual, FM 100-30 (TEST), Headquarters, Department of the Army, Washington, D.C. (August 19, 1971).

2. "Nuclear Weapons Employment," Staff Officer's Field Manual, FM 101-31-3, Headquarters, Department of the Army, Washington, D.C. (February, 1968).

3. J. B. Knox, T. V. Crawford, and W. K. Crandall, "Potential Exposures from Low-Yield Free Air Bursts," UCRL-51164, Lawrence Livermore Laboratory, University of California, Livermore, California (1971).

4. P. D. LaRiviere et al., "Local Fallout from Nuclear Test Detonations (U) Volume V, Transport and Distribution of Local (Early) Fallout from Nuclear Weapons Tests (U)," Stanford Research Institute, Menlo Park, California (May 1965) SECRET RESTRICTED DATA.

5. "Operational Aspects of Radiological Defense," Field Manual, FM 3-12, Departments of the Army and the Navy, Washington, D.C. (August 21, 1968).

6. "Nuclear Weapons Employment Doctrine and Procedures," Staff Officer's Field Manual, FM 101-31-1, Headquarters, Department of the Army, Washington, D.C. (February 1968).

7. "The Division," Field Manual, FM 61-100, Headquarters, Department of the Army, Washington, D.C (November 1968).

8. C. F. Miller, H. Lee, and J. D. Sartor, "Introduction to Radiological Defense Planning," Stanford Research Institute, Menlo Park, California (May 1965).

9. "Fallout Prediction," Technical Manual, TM 3-210, Department of the Army, Washington, D.C. (May 1962).

10. H. Lee, P. W. Wong, and S. L. Brown, "SEER II: A New Damage Assessment Fallout Model," DNA 3008F, Stanford Research Institute, Menlo Park, California (May 1972).

11. "Catalog of Surveillance, Target Acquisition, Night Observation Equipment and Systems (U)," Department of the Army, U.S. Army Electronics Command, Fort Monmouth, New Jersey (July 1972) CONFIDENTIAL.

12. "Infantry Reference Data," Volumes I and II, U.S. Army Infantry School, Fort Benning, Georgia (July 1970).

13. "Chemical, Biological, Radiological, and Nuclear Defense," Field Manual, FM 21-40, Headquarters, Department of the Army, Washington, D.C. (May 1971).

14. "Tactical Operations in the NBC Environment," U.S. Army Command and General Staff College, Fort Leavenworth, Kansas.

15. "Department of Defense Land Fallout Prediction System, Vol. I, System Description," DASA-1800-I, Technical Operations Research, Burlington, Massachusetts (June 1966).

16. "Electronics Systems Planning--ESP (U)," Proceedings of Advanced Planning Briefing, 6-7 April 1973, Volume II, U.S. Army Electronics Command, Fort Monmouth, New Jersey (February 1973) SECRET.

17. "Surveillance, Target Acquisition and Night Observation (STANO) Operations," Field Manual, FM 31-100 (TEST), Headquarters, Department of the Army, Washington, D.C. (May 1971).

18. "Basic System Description, Technical Summary, Tactical Operations System (U)," U.S. Army Computer Systems Command, Fort Belvoir, Virginia (15 May 1971).

19. "DA Approved Material Need for the Tactical Operations System (U)," U.S. Army Combat Developments Command, Intelligence and Control Systems Group, Fort Belvoir, Virginia (November 1972) CONFIDENTIAL.

20. "Electronic Systems Planning--ESP (U)," Proceedings of Advanced Planning Briefing, 6-7 April 1973, Volume I, U.S. Army Electronics Command, Fort Monmouth, New Jersey (February 1973).

21. "System Development Plan, Tactical Fire Direction System--TACFIRE," U.S. Army Computer Systems Command, Fort Belvoir, Virginia (March 15, 1971).

22. "TARS-75 Field Evaluation," Training Text, TT 30-20-1, U.S. Army Combat Developments Command Institute of Combined Arms and Support, Fort Leavenworth, Kansas (October 29, 1969) CONFIDENTIAL.

Appendix A

A QUESTIONNAIRE FOR EVALUATING DOCTRINE AND READINESS FOR NUCLEAR FALLOUT HAZARD ASSESSMENT

One of the basic tasks of this battlefield radiation study was a review and analysis of current U.S. military doctrine in the operational aspects of land combat radiological defense. As part of this task, it was anticipated that a broad sampling of service views on improvements needed in the doctrine and on readiness to deal with radiation hazards could be obtained. The most economical and expeditious means of accomplishing this appeared to be to distribute a questionnaire to a representative group of military personnel and to analyze the responses. The questionnaire prepared for this purpose appears at the end of this appendix.

The questionnaire was not circulated because of a DoD policy placing restrictions on this practice, and also because of the limited time available. Instead, the questionnaire was used as a guide for the conduct of interviews with a limited number of active and retired military officers. The results of these few interviews indicated that it might be beneficial to use the questionnaire within one or more selected military organizations; for example, the student body at the Army's Command and General Staff College or a cross section of officers and noncommissioned officers in a combat ready Army division.

The questionnaire might be criticized as having value only if circulated among personnel having experience and training in radiological defense. Insofar as the Army is concerned, such criticism would imply that the provisions of Army Regulation No. 220-58, "Organization and

Training for Chemical, Biological, and Radiological (CBR) Defense" and the U.S. Army Forces Command Supplement 1 thereto are not being implemented effectively. Those regulations prescribe the responsibilities of each commander to ensure that his unit is prepared to carry out its mission effectively when operating in a CBR environment and the training required to attain desired standards of proficiency.

In one of the interviews based on the questionnaire, an Army officer with a very good background of experience and training in radiological defense matters expressed the following opinions:

(1) General views:

- Doctrine--Current doctrine is believed to be adequate, given the current status of radiac equipment, communications, and nuclear radiation hazard evaluation techniques, all of which are oriented to a manned and manual mode of operation.
- Readiness--A well trained division should have an adequate degree of readiness to execute current procedures. The key to readiness is training at available schools and within units, and the play of nuclear burst reporting, fallout prediction and warning, and reporting of fallout radiation dose rates in field exercises.

(2) Within a division area, postulating an enemy preparation for breakthrough, about three to ten (probably closer to ten) enemy nuclear bursts might fall in the first day of a nuclear battle. This number would go down on the second and third day. (A somewhat different estimate might be made by an officer with recent high-level staff operational planning experience.)

(3) Only about five percent of these bursts would produce fallout, particularly if the enemy planned to advance; these would probably not be intentional.

(4) The doctrine and procedures would be implementable in most cases.

(5) The initial NBC 4 reports would take about ten minutes to pass through channels from company to division.

(6) A good CBRE team at the division TOC should be able to plot and evaluate radiation dose-rate measurements for a single nuclear burst in 15 to 20 minutes.

(7) A company-size unit should be able to start moving out of a radiologically hazardous area within less than ten minutes after a division order is issued, particularly if advance warning of probability of move is received.

(8) Selection of escape routes should be based on the best information available.

(9) Present fallout assessment doctrine and procedures are adequate, but they are not tested often enough. Realistic tests are difficult to stage.

(10) He agreed that doctrine and procedures appear to be based on a single detonation. He did not agree that they are generally inapplicable for multiple detonations, although recognizing the problems in assessing overlapping fallout patterns.

(11) He agreed that doctrine and procedures have merit only if nuclear battle is punctuated by periods of nuclear inaction, but considered that this is probably the most likely situation.

(12) Current doctrine and procedures can be improved, but probably not much at company level. Current ones are probably adequate for the present system. Adequacy depends on the command level, since longer planning time is associated with higher levels of command.

(13) The readiness of a field forces unit to respond to radiation assessment procedures depends on its stage in the training cycle. At advanced stages, the readiness should be fair to excellent.

(14) An improved battlefield radiation assessment system would be an advantage and could very likely be a decisive factor in affecting the outcome of a nuclear battle. No suggestion was made for types or areas of improvement necessary, and no current plans for improvement were known.

(15) The best source for credible information of the type sought in the questionnaire would probably be selected personnel in a combat ready division (unit commanders, staff operations officers, chemical officers, and personnel with CBR responsibilities).

FALLOUT ASSESSMENT QUESTIONNAIRE

1. Rank:

2. Organization:

3. Position in Organization:

4. Indicate experience in NBC matters during past 5-10 years:

   ☐ School, ____weeks ☐ Staff, ____months ☐ Field Exercises ☐ CPXs

5. How would you rate your knowledge in the area of tactical nuclear warfare operations? Please check one.

   ☐ an expert ☐ very knowledgeable ☐ better than average

   ☐ average ☐ below average

6. Assume that tactical nuclear warfare is initiated to support an enemy breakthrough in a division area of operations. How many enemy bursts do you think will occur in this division area on the first day?

   ☐ less than 5 nuclear bursts
   ☐ 5 to 20 nuclear bursts
   ☐ 20 to 50 nuclear bursts
   ☐ 50 to 100 nuclear bursts
   ☐ more than 100 nuclear bursts
   ☐ not knowledgeable

7. What about the second and succeeding days? Please indicate estimate of number of enemy nuclear bursts in the division area.

   second day of battle: ________to__________nuclear bursts
   third day of battle: ________to__________nuclear bursts

8. Do you think there will be many fallout producing enemy bursts? Please check one.

   ☐ less than 1 percent
   ☐ about 5 percent
   ☐ about 10 percent
   ☐ about 25 percent
   ☐ more than 25 percent
   ☐ not knowledgeable

9. Do you think these enemy fallout producing bursts will be intentional?

   ☐ Yes ☐ No

10. How would you rate your knowledge on the current fallout assessment doctrine and procedures?

   ☐ an expert ☐ above average ☐ average ☐ below average

11. How do you rate the adequacy of current fallout assessment doctrine and procedures?

☐ excellent ☐ adequate ☐ not bad ☐ not good ☐ poor

12. After the initiation of a nuclear attack, that is, a situation where some nuclear detonations have occurred and more may follow, how effectively do you consider that the current fallout assessment doctrine and procedures will be carried out by personnel in the danger area?

☐ essentially as planned
☐ good enough to produce useful information
☐ poorly, with inconclusive results

13. Assuming that monitoring dose rate readings are made at company/battery level and then passed through channels to division, what is your estimate of the time required (assuming monitoring and command structure essentially intact):

- For the information to reach division?

☐ less than 10 min.	☐ 30 min.
☐ about 10 min.	☐ 40 min.
☐ about 20 min.	☐ longer than 40 min.

- For the data to be plotted and evaluated (AFTER IT ARRIVES AT DIVISION TOC)?

☐ about 5 min. or less	☐ 20 min.
☐ 10 min.	☐ 30 min.
☐ 15 min.	☐ 40 min. or more

14. Assume that data plotted at division by the CBRE shows that several company size combat units are in a hazardous radiological situation, that their mission does not preclude moving, that organic vehicles are available, and that there are usable escape routes. How soon after a division order is issued would movement begin?

☐ 10 min. or less	☐ 45 min.
☐ 20 min	☐ 60 min.
☐ 30 min	☐ 90 min. or more

15. In the foregoing situation, would you base your selection of escape routes on:

- ☐ monitoring data available to company and/or battalion commander (i.e., information available with least delay)
- ☐ monitoring data available to CBRE at TOC (i.e., more complete data, but which may necessitate greater delay)
- ☐ monitoring data plus ground and/or aerial survey data available to CBRE at TOC (i.e., even more complete data, but at the expense of even greater delay)

16. Considering the delay time and the possible changes in the battlefield fallout conditions caused by additional fallout producing bursts, do you consider that fallout dose-rate measurement data are useful for planning tactical maneuvers?

- ☐ generally useful
- ☐ conditionally useful
- ☐ generally not useful

17. Opinions have been expressed that the doctrine and procedures appear to be based, for the most part, on single detonations and are generally inapplicable for multiple detonations. What is your opinion?

☐ agree ☐ disagree

18. Opinions have been expressed that the doctrine and procedures have merit only if the nuclear battle is punctuated with periods of nuclear inaction, permitting assessments of static situations, e.g., after total fallout cessation. What is your opinion?

☐ agree ☐ disagree

19. Do you think current doctrine and procedures could be significantly improved?

☐ Yes ☐ No

20. Have you been trained to (check all that are applicable)

- ☐ prepare NBC 1 reports ?
- ☐ prepare NBC 4 reports ?
- ☐ read a radiac instrument ?
- ☐ perform CBR officer functions ?

21. Are our methods of training for operations in a nuclear radiation environment adequate?

☐ Yes ☐ Barely ☐ No

22. How much emphasis is placed on this type of training?

☐ sufficient ☐ insufficient

23. How do you rate the current readiness of our ready divisions to respond to current radiation assessment doctrine and procedures in the event of a tactical nuclear war?

☐ excellent ☐ fair ☐ poor ☐ not knowledgeable

24. Do you think a significant advantage can be gained by an improved battlefield radiation assessment system?

☐ Yes ☐ No

25. If your answer to 24 is yes, please indicate the types or areas of improvement needed:

26. Do you think that improvements suggested in 25 or any improvements at all could be an important factor in affecting the outcome of a nuclear battle?

☐ very likely ☐ possibly ☐ unlikely ☐ inconsequential

27. Do you know of any improved system that is presently being developed, planned or under consideration?

☐ Yes ☐ No

28. If your answer to 27 is yes, please specify.

29. If you have any statement on the general area covered by this questionnaire or on the questionnaire itself that you would like to express, please do so.

Appendix B

SYSTEM EVALUATION

A. Conceptual Procedure

The utility of current and suggested fallout radiation assessment systems has been qualitatively discussed and subjectively evaluated in a general manner. Certain system elements have also been quantitatively evaluated with respect to specific applications and specific conditions. Although these evaluations indicate that some operational advantages could be gained by system improvements, they do not provide adequate specificity to provide guidance on overall system improvement requirements; that is, the operational advantages that can be gained by various improvements were not quantified. Although absolute quantitative evaluations are probably impossible, the data derived from repetitive war game exercises will provide measures of the operational advantages of various system improvements.

An alternative evaluation procedure, which is less definitive but also less costly, is to parameterize the various aspects of the problem and do a comparative analysis. In general, the procedure is to identify the elemental factors that affect a system's utility, to describe the effects in mathematical terms, and to calculate the results for various inputs.

The battlefield radiological assessment problem entails three basic considerations: (1) the rate of developments, (2) the ability to assess developments, and (3) the ability to cope with the assessed developments. Unless an ability to cope with a development exists, no purpose is served by development assessment. Fallout radiation assessment operations require time and effort. As the rate of surface bursts is increased, the rate of radiological changes occurring on the battlefield is increased and therefore the time available to respond to the changes caused by each is decreased. Air bursts produce no fallout in clear weather, and in the event of rainout or washout they can be treated as surface bursts; that is, as fallout producing bursts. As the rate of air bursts over the rate of surface bursts is increased, however, the relative importance of fallout on the battlefield and consequently the importance of fallout radiation assessments is decreased. Finally, as the sum of all nuclear employments (surface and air bursts) is increased, the capability to respond is decreased because of personnel casualties, system component damage, and various other created operational constraints.

The total weapon employment, both surface and air bursts, can be conveniently expressed in kT/1000 square miles (1000 square miles being an approximation of a division's area of responsibility). In general, the capability of a system with interdependent vulnerable components can be expected to degrade slowly from a threshold level of weapon employment, and then to degrade at an accelerated rate when the system begins to become unhinged. The capability, C, of the system can therefore be estimated by

$$C = \left(\frac{W_2 - W}{W_2 - W_1}\right)^{kW/W_2} \quad \text{(B-1)}$$

for $W_1 \leq W \leq W_2$

where

W = the total nuclear yield employed in time t

W_2 = the total yield that will completely destroy the system

W_1 = the total yield required to initiate system degradation

k = a constant whose value depends on when the system begins to unhinge.

Note that $W = (S + A)t$, where S and A are defined in the paragraphs that follow.

The fractional reduction in the available time, T, for a system to respond to surface bursts can be estimated by

$$T = \frac{S_3}{S} \qquad \text{(B-2)}$$

for all $S \geq S_3$

where

S = the surface burst rate

S_3 = the surface burst rate threshold where time begins to be inadequate and fallout information begins to be delayed.

The rate of radiological change also affects an organization's ability to cope with the radiological change; consequently the operational utility, U, of the system can be estimated by

$$U = \frac{S_5 - S}{S_5 - S_4} \qquad \text{(B-3)}$$

for all $S_4 \leq S \leq S_5$

where

S_4 = the surface burst rate threshold at which the rate of radiological change begins to affect the operational utility of the system

S_5 = the surface burst rate at which the operational utility of the system is zero.

The operational utility of a system is dependent on the speed of the system, because extra time to cope with the radiological changes is made available by a faster assessment system.

The reduction in the importance, I, of the fallout assessment system because of the ratio of air bursts to surface bursts can be estimated by

$$I = \frac{S}{\alpha A + S} \qquad \text{(B-4)}$$

where

A = the air burst rate

S = the surface burst rate

α = a constant.

The value, V, of a fallout radiation assessment system is then

$$V = CTUI \quad . \qquad \text{(B-5)}$$

It is recognized that the rate of weapon employment is an inadequate measure of battlefield events and effects, and that the combination and sequence of events in a nuclear battle cannot be adequately described mathematically. Nevertheless, the above equations, or improved versions of them, can be used to construct a scale of numerical estimates of the relative merits of alternative fallout assessment systems. The relative merit of an improved system over the current system is

$$\frac{V_i}{V_c} = \frac{(CTUI)_i}{(CTUI)_c} \qquad \text{(B-6)}$$

where the subscript i is for the improved system and the subscript c is for the current system. The ratio V_i/V_c is not constant and will vary from unity at low weapon employment rates to infinity at high weapon employment rates, where C_c or U_c is equal to zero. At very high employment rates, C_i and U_i will also equal zero, and neither system is of any value. Since the yields in Eq. B-1 are merely equal to the product of weapon employment rates and time, a convenient rate unit is kT/hr/1000 mi^2, and the time unit is hours.

B. Input Data Requirements

The constant inputs associated with each system are W_1, W_2, k, and S_3. The rates S_4 and S_5 are only partially dependent on the assessment system, and I and α are independent of the assessment system. Since I is independent of the assessment system, it has no influence on the V_i/V_c ratio; however, it does deserve consideration in evaluating a system. The evaluation of a battlefield radiation assessment system can therefore be reduced to the determination of these inputs in the context of their application.

For example, suppose it could be determined that the inputs for the current assessment system and for an improved system are:

	Current System	Improved System
W_1 kT/1000 mi^2	50	100
W_2 kT/1000 mi^2	1000	2000
k	0.8	0.6
S_3 kT/hr/1000 mi^2	5	10
S_4 kT/hr/1000 mi^2	5	7
S_5 kT/hr/1000 mi^2	100	140
α	0.2	0.2

Suppose also that the air burst rates are nine times the surface burst rates. The assessment system values resulting from these assumptions, for various weapon employment rates at two different elapsed times, are as shown in Figure B-1. The V_i/V_c ratios for various weapon employment rates for various elapsed times are given in Table B-1.

Table B-1

V_i/V_c RATIOS

Rate S + A (kT/hr/1000 mi^2)	Elapsed Time (hours)			
	1	4	8	15
50	1.0	1.02	1.13	2.03
100	2.07	2.34	5.01	∞*
150	2.13	3.01	∞*	†
200	2.20	5.20	∞*	†
300	2.39	∞*	†	†
400	2.70	∞*	†	†
500	3.20	†	†	†
800	10.4	†	†	†

*Current system destroyed.

†Both systems destroyed.

A nuclear battle can be expected to wax and wane with time, and the value of any assessment system will change according to the circumstances. Since the specifics of a nuclear battle cannot be predetermined, Table B-1 can only be considered semiquantitative. Isolating the various factors affecting a system's value, however, provides a means for examining the problem by parts and thereby makes the overall problem approachable.

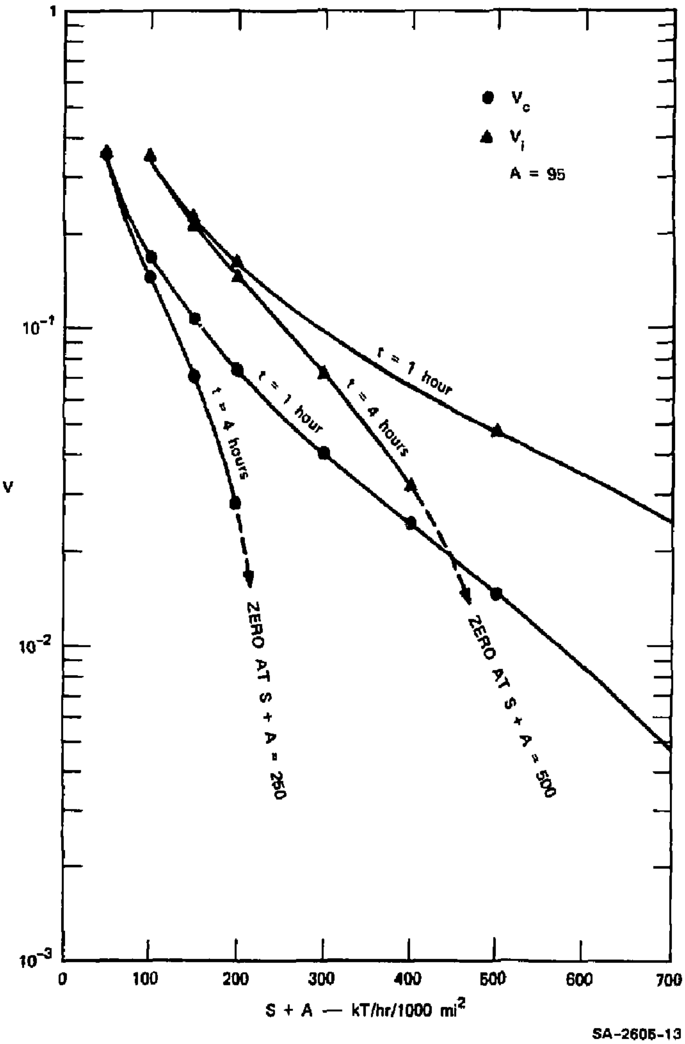


FIGURE B-1 CALCULATED SYSTEM VALUES FOR EXAMPLE INPUTS